MARINE ZOOLOGY OF OKHAMANDAL (INDIA)

HORNELL

PART I

1909

REPORT ON THE MARINE ZOOLOGY OF OKHAMANDAL IN KATTIAWAR

HIS HIGHNESS SAYAJI RAO III., GAIKWAR, G.C.S.I.,
SENA KHAS KHEL SAMSHER BAHADUR,
MAHARAJA OF BARODA.

REPORT

TO THE GOVERNMENT OF BARODA ON THE

MARINE ZOOLOGY OF OKHAMANDAL IN KATTIAWAR

BY

JAMES HORNELL, F.L.S.

Bureau of Fisheries, Madras, and formerly Marine Biologist to the Government of Ceylon

WITH SUPPLEMENTARY REPORTS ON SPECIAL GROUPS BY OTHER ZOOLOGISTS

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14, HENRIETTA STREET, COVENT GARDEN, W.

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RICHARD CLAY AND SONS, LIMITED,
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PREFACE

The investigation which furnished the collections whereon are based the reports comprised under the present cover owed its inception to the enlightened policy pursued by His Highness Maharaja Sayāji Rao III., Gaekwar of Baroda, for the educational and material development of the historic State which is so fortunate as to be ruled by him.

Naturally the technical inquiry at Okhamandal which His Highness honoured me by entrusting to me to carry out, had the improvement of the economic marine resources of that district as its foremost object, and indeed its *raison d'être* from an administrative standpoint; yet, with a generosity towards the furtherance of pure science too rarely found among the heads of States, His Highness most willingly agreed to bear the entire expense involved in the publication of any scientific reports written by specialists upon the zoological collections made during the inquiry. He was also pleased to express the wish that such papers should be presented in the best possible form, and that no efforts were to be spared in their satisfactory illustration.

Hitherto the attention of zoologists dealing with the fauna of Indian seas has been directed in the main towards the investigation of the species inhabiting the deeper zones; in this connection I have only to cite the classic monographs with which the name of the Indian Marine Surveying steamer "Investigator" and of Major Alcock, F.R.S., late Superintendent of the Calcutta Museum (Natural History), will ever be associated with all honour. Comparatively little attention

has been bestowed upon the fauna of the littoral zone and inshore shallow water, except in the case of the Gulf of Mannar, where that of the Ceylon side has been ably dealt with by Prof. Herdman, F.R.S., and the workers associated with him, while the zoology of the Indian side has received considerable attention from Dr. Thurston, the versatile Superintendent of Madras Museum, from Prof. Dendy, F.R.S., and other well-known zoologists in England and India. It is hoped, therefore, that the following reports, dealing as they do exclusively with the marginal waters of a little-known region on the West Coast of India, may prove valuable as a local monograph—the first of its kind in India—and from the standpoint of geographical distribution.

In Part I. I have to acknowledge with grateful thanks the invaluable assistance of Mr. Thomas Southwell, A.R.C.S., F.L.S., Professor J. Arthur Thomson, M.A., Mr. George Crane, B.Sc. of Aberdeen, and Sir Charles Eliot, Sheffield University. The first-named, whom it was my good fortune to have as my scientific assistant during the last eighteen months of my service in Ceylon, besides contributing a report on the Anomura, collaborated with me in the description of a new species of Pinnoteres and also afforded me much help in other directions. Mr. Southwell has now in hand a report upon the Actinozoa which I hope to include in Part II.

The report on the Alcyonarians of Okhamandal, now furnished by Prof. J. A. Thomson and Mr. George Crane, is particularly valuable on account of the beautifully executed coloured plate which accompanies it and which renders identification easy of the principal species of this group found in the waters of the Gulf of Kutch. The short contribution by Dewan Bahadur V. M. Samarth is of great interest as indicating, among other things, how a wise and progressive rule, such as that exercised by His Highness the Gaekwar, has the power of penetrating every department of government and of endowing each with a portion of the same spirit of enlightened progress.

The whole of the photographs reproduced, except the frontispiece, are the work of the Vividha Kala Mandir, Baroda, whose representative accompanied me

during the greater part of the time spent in Okhamandal, and whom I am glad to have this opportunity to thank for the great assistance he rendered, often enough under circumstances of great personal discomfort.

As regards the groups of animals yet to be described I have received from Prof. A. Dendy, F.R.S., our greatest authority upon the Sponges, the promise of a report, which is the more valuable seeing that this phylum is especially rich in species in the collections from Okhamandal. Mr. Edward T. Browne, M.A., University College, London, has undertaken to report upon the Medusæ, while Miss Thornely will report upon the Hydrozoa and Polyzoa and Prof. Herdman, F.R.S. upon the Ascidians. On my own part I hope to furnish contributions upon certain of the remaining groups, together with a general survey of the geographical and vertical distribution of the more noteworthy species and groups represented in the collections.

For the benefit of those readers whose acquaintance with India is not intimate, it may be of interest to mention that Baroda is one of the greatest of the self-governing States of India, having an area of over 8,000 square miles and a population at the last census (1901) verging upon 2,000,000. The present Maharaja is essentially a man of action; he may dream dreams, but his waking hours are devoted to strenuous effort to turn them into practical realities. To the introduction of new industries and the improvement of indigenous ones he has given the greatest attention; he has travelled far and wide through Europe and America to gather ideas and information at first hand pertinent to the schemes he is elaborating for the economic and social advancement of his State. His Highness is specially concerned in fostering the arts of the hereditary craftsmen of India, whose productions tend to deteriorate and decay as the cheap and shoddy wares of Europe and the new Japan crowd them from the shelves and counters of the bazaars.

As the basis of all reform, the Maharaja is convinced of the necessity of placing within the reach of even the humblest of his subjects educational opportunities well-considered for their particular requirements; at the present

moment education is not only free, but is compulsory as well in Baroda. By the enlightening and levelling influences of this system of universal education His Highness hopes so to raise the lower castes that the fetters of caste itself will automatically fall away, but so gradually that the evils of a sudden social revolution shall be avoided. The Maharaja is certainly entitled to be considered the most important personal factor in social reform in India; indeed none but a powerful and orthodox Hindu ruler such as he is dare to approach with any chance of success the domestic problems which fetter Indian society. Among other measures of reform, he has done much for the cause of female education, not only within the bounds of his own State but throughout all Hindu India; he is a staunch advocate of a relaxation of the rigorous enforcement of the purdah system, and by his enactments he has so raised the minimum marriage age, that the evils of child marriage have been put an end to in Baroda.

Those interested in the social and economic regeneration of India should study well and in detail the history of Baroda during the present reign, for therein they will find the record of much attempted and much accomplished in spite of many failures. The present volume is the story of the work done in one of these pioneering attempts.

In conclusion, I desire to thank once more all the Baroda officials who gave their ungrudging help to me in the present investigation; I wish them long life and every possible success in their careers, and especially do I wish all honour and happiness to Dewan Bahadur V. M. Samarth, who, I understand, is about to retire from the service of his State at an early date.

My hearty thanks are also due to Major A. K. Condon, the Assistant British Resident at Dwarka during my visit, for his great hospitality and unvarying kindness and courtesy. I shall ever retain a vivid recollection of the warmth of the welcome which he was so good as to extend to me. To observe the wonderfully good relations subsisting between him and the officers and men of the Okha battalion was not the least interesting of my experiences, and I

trust the battalion may always have a Commander as sympathetic and careful of their well-being as MAJOR CONDON was.

The prosperity of Baroda is a very sincere wish in my heart, and I trust that HIS HIGHNESS THE MAHARAJA GAEKWAR may long be spared to guide its destinies upon the path of enlightenment and social and material progress; may the great reforms he has at heart come early to fruition and maintain Baroda's well-founded claim to be the most enlightened self-governing State in India.

JAMES HORNELL.

MADRAS, *April* 10*th*, 1909.

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Photo by Vriddha Kala Mandir, Baroda.]

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View of Dwarka from the south bank of the Gumpti creek.

REPORT

TO THE GOVERNMENT OF BARODA

ON THE PROSPECTS OF

ESTABLISHING A PEARL FISHERY

AND OTHER MARINE INDUSTRIES ON THE COAST OF OKHAMANDAL,

BY

JAMES HORNELL, F.L.S.,

Bureau of Fisheries, Madras, and formerly Marine Biologist to the Government of Ceylon.

By arrangement with the Ceylon authorities my services were lent to the Government of Baroda at the end of 1905 for the purpose of investigating the economic marine resources of the coast of Okhamandal, an outlying portion of His Highness the Gaekwar's possessions, forming the north-west extremity of the peninsula of Kattiawar. Pearl oysters had been noted in small numbers along the coast-line, and my attention was to be directed specially to an examination of the possibilities of developing a remunerative pearl fishery.

Leaving Ceylon on 30th November, 1905, I reached Dwarka, the chief port of Okhamandal, six days later. By the courtesy of the authorities, His Highness's steam launch "*Pari*" had been sent round to Dwarka, and was awaiting my arrival, while the Vahivatdar, the principal revenue officer of Okhamandal, Mr. Kashinath B. Pradhan, with the assistance of Mr. Sunderlal, the Executive Engineer, had all arrangements perfected for the immediate commencement of the investigation. Without the abounding energy and intimate local knowledge possessed by Mr. Pradhan, and the professional skill of Mr. Sunderlal, the comparatively short time at my disposal would have proved inadequate to that extensive and minute examination of the littoral waters necessary before I could formulate conclusions sound and of real economic value.

It had been a question of anxious consideration as to the time best suited to carry on the investigation, especially as my duties in Ceylon precluded my being away save in summer (May to September), or during December and part of January. The latter period was, as I have said, the period eventually chosen, the principal reason being that at this time the weather is normally sufficiently favourable to allow of investigation being carried on both in the channels around Beyt Island, upon the reefs adjoining, and also upon the exposed seaward or western coast of Okhamandal promontory.

Results showed that this choice was the best possible, as at any other time the violence of the south-west monsoon renders the western coast inaccessible.

Fig. 1.—Shells of the black-lip Pearl Oyster (*M. margaritifera*) on sale in the Dwarka bazaar. They hail most probably from the Persian Gulf.

A considerable amount of preliminary evidence had been gathered by Mr. Pradhan, the Vahivatdar, at the instance of the Sar Subha of His Highness the Gaekwar's State, the cultured and progressive Dewan Bahadur V. M. Samarth, B.A., to whose energy and enlightened foresight the inception of the present inquiry is largely due.

The facts pointing to the possibility of developing the resources of the seas and shores of this portion of the Baroda dominions were principally the two following, viz. :—

(*a*) The neighbouring State of Jamnagar, of which the coast-line is a continuation

eastwards of the northern sea margin of Okhamandal, has for a long period carried on a small and primitive pearl fishery in the shallows on and around the rocky reefs that stud the southern margin of the Gulf of Kutch.

(*b*) Rumours of finds of pearl oysters and of pearls, by fishermen and others upon the Okhamandal coast, had several times come to the knowledge of the authorities, who had in consequence instituted search several times in the endeavour to ascertain the real facts.

Difficulties in obtaining divers, reliable as well as competent, were met with, and no conclusive evidence had been obtained when Mr. Samarth and Mr. Pradhan took up the investigations once more.

No local divers are procurable in the Gulf of Kutch, the Jamnagar pearl fishery and the Okhamandal chank fishery being carried on by the primitive method of wading in the shallows, the fishermen taking advantage of the great fall of level that occurs on the days of high spring tides. Accordingly, besides including dredges and water-telescope in the apparatus taken, I also took with me, upon the suggestion of the Baroda Government, three of the best of the divers who were then permanently retained by the Ceylon Pearl Fishery Department for periodic inspection of the pearl banks.

I should add that I was also informed that chank-fishing is an historic minor industry on the Okha coast, and that edible oysters are also found in several bays and creeks.

Dredging, diving, and shore collecting were carried on almost continuously from 9th December, 1905, to 13th January, 1906, during ten days whereof I had the great pleasure and advantage of the advice, companionship, and hospitality of the Sar Subha, Dewan Bahadur V. M. Samarth. I need not say that his countenance of my work facilitated and expedited matters very greatly, and words fail me wherein to express my appreciation of his personal kindness and his untiring zeal in ensuring that no effort should be spared to help the investigation forward. In lonely and unfamiliar circumstances it was indeed an unlooked-for delight, and one the more pleasant by being unexpected, to meet one so widely read and deeply versed in the literature of both East and West as Mr. Samarth. The evenings passed in discussion after the day's work was completed, will remain as delightful memories of Dwarka and Beyt through the rest of my life, and make the remembrance of this investigation a joy ever to be recalled with pleasure.

The performance of the Tamil divers, taken from Ceylon, was disappointing, and had I not had the dredges to fall back upon the inquiry could not have been carried through successfully. The cause of the unsatisfactory diving lay in the chilliness of the December and January winds and the comparatively low temperature of the water. We may console ourselves with the thought that divers of no other race available in India would have given better results. The same trouble would have been found had

Arab divers been employed. My experience is that, if anything, Arabs are more sensitive to cold than Tamils. In the Persian Gulf, for instance, no diving for pearl oysters goes on during the winter months—those during which we worked at Okhamandal—work being confined to the hot summer months of June to September; the two intensely hot months of July and August are considered the best and constitute the height of their season.

In consequence, while the results obtained are sufficient to enable me to pronounce definitely upon most matters which I set out to examine, it must be remembered that the investigation has not been exhaustive. Five weeks' work in marine biology, carried out single-handed, is inadequate to do more than clear away initial difficulties and misconceptions, and to show the most suitable lines for the more detailed investigations of my successors. It has been good pioneering, and just sufficiently ample to enable the economic potentialities of the locality to be assessed for some of the most likely organisms.

The collections made of marine animals and plants are large and important for many groups. Sponges, cœlenterates (especially hydroids and alcyonarians), crustaceans, worms and algæ are notably well represented. The plankton (minute free-swimming life of the sea) I could wish to comprise a larger number of samples, but the material will be found ample, I believe, to enable an approximate census to be made both of the relative and the absolute proportions present in the Okha waters of the chief organisms which contribute to the dietary of the two forms of pearl oysters found in this locality.

These collections have now been sorted and have been placed in the hands of specialists to be reported upon in detail.

It may be well to point out here that the examination and identification of the hosts of animals and plants comprising the marine fauna and flora of the Gulf of Kutch have much more than an academic and purely scientific interest. Within the assemblage are comprised enemies of the pearl oysters—sponges, corals, starfishes, worms, fishes—some that burrow into and destroy the commercial value of the shell, others that kill oysters directly and yet others that compete for food and space and foothold with the oyster, and which, if excessively numerous, may entail starvation on the mollusc and even elbow it out of existence locally. The comparative abundance of seaweeds is a factor of great moment, for their spores at certain seasons constitute a great proportion of the food of oysters, while the rankness of their growth, as I can testify, so masks and hides the presence of oysters that pearl-fishing in December and January is impossible in practice. It is matter for regret that I cannot see the same localities in June or July when, I believe, this extraordinary growth of weeds dies down annually.

Nature does not always hold an even balance; it dips occasionally and only an intimate acquaintance with the bionomics of the whole assemblage of the local fauna can enable us to devise effective cultural measures and to guard those deposits of

economic value from the active aggression of predatory enemies and from the passive competition of creatures of similar habitat or dietary.

As a result of the information obtained by dredging, diving, and shore-collecting during the five weeks of the investigation, it appears that the seaward or western coast of Okhamandal may be eliminated from further consideration. Its aspect, fronting the terrific onset of the south-west monsoon surf, renders it too exposed to permit of exploitation from May to September, save for a paltry number of chanks that may be picked up in the shallows at low tides. The turmoil of the breakers is too great to permit of existence on the littoral and down to a depth of twelve to fifteen fathoms save to such quickly growing animals and plants as can spring into luxuriance in the comparatively quiet interlude afforded by the north-east monsoon season, or to such others as have so modified their structure and habits as to be able to withstand the battering of the surf and the wrench of a violent undertow.

Not a trace of pearl oysters, living or dead, was found; not even the smallest fragment of a valve. From this and the physical circumstances of the locality I am satisfied that no deposit or bed of pearl oysters has existed here since the configuration of the adjacent coast assumed its present aspect. Even if they did exist, it would in practice be impossible to fish them, either by means of the dredge or by the help of naked divers, the former because of the rough nature of the bottom—great surf-worn boulders in many places, the latter because in the season available, winter, chill winds prevail with too low a temperature.

By means of the dredge and occasional diving descents we also went over all the likely localities in the deeper off-shore waters, notably the great bank named Gurrur on the Admiralty Chart. This extensive bank which lies five to six miles west of Okha Point, measures ten miles in length by one and a quarter miles in breadth, with depths of from six to ten fathoms over it; it slopes rapidly into deeper water on the landward side as well as on the seaward or western aspect. Judging by the analogy of the similarity in depth, in distance from the mainland, and in apparent configuration with some of the large pearl banks in the Gulf of Mannar, I had some hope of finding here likely biological conditions for pearl oysters. Such hopes were disappointed; the bank proved to be an irregular plateau—a flat-topped rocky reef covered more or less thickly with rolled and water-worn fragments of shells and small pieces of dead coral. There appeared to be an almost complete dearth of life. The bank is barren and washed by continual currents that keep the bottom in a constant flux and reflux. The day devoted to its examination (December 22nd) was comparatively fine, and even then the launch drifted at quite four knots an hour, while the divers reported such a strong bottom-current as to render it almost impossible to keep a position on the bottom for even a few seconds. With a light north-east wind and calm sea the water on the bank was distinctly muddy and in contrast to the brighter water beyond its margin, so that even without resort to

the lead we could tell the moment we arrived on this bank. As pearl-oyster ground the Gurrur is hopeless—a battle-field of tide and current.

On the northern aspect of Okhamandal more favourable conditions prevail, as the shore-line and the shallows there are in a large measure protected from the violence both of the south-west and north-east monsoons. Especially is this the case with the great bight formed by the deep horseshoe curve of what may be termed Beyt Harbour, using the name in a widely comprehensive manner. This bay or harbour has as its two horns, Yamiani Point and Samiani Island on the west, and Poshetra Point on the east, with the long, irregular mass of Beyt Island lying athwart the entrance, and sending irregular promontories so far within the bay itself as to reduce the latter to little more than a reef-choked, rather wide channel between the island and the mainland. Through this passage, Beyt Harbour, a strong tide-race runs, bearing food matter in profusion to every corner of the littoral. The rocky reefs and islets that crowd the western and south-western sections set up an intricate network of cross currents and eddies, ever changing with the phase of the tide, and aiding powerfully in the distribution of the planktonic food supply. Never have I seen a richer and more diversified fauna within such a limited area. Within a distance of eight miles the faunal association changes completely full half a dozen times. On the rocky littoral of Adatra, we have a profusion of massive corals, sponges, and alcyonarians; half a mile on we reach the Zostera and Halophila prairies of Aramra with muddy flats supporting the edible oyster in profusion.

Another two miles and the muddy rocky littoral of Kiu reveals at low tide the strangest forest in miniature we could imagine. Over several acres of the lowest zone of the littoral uncovered at the greater spring tides, myriads of the short-branched parchment tubes of the polychæt worm *Eunice tubifex* rear their stalks above the surface to a height of eight to ten inches. Plate III. is a view of a portion of this strangely covered ground, a scene unique in the whole of my experience. Dense tufts and tassels of long-branched, elegant Bryozoa drape and smother from view many of the tubes, the stalks and branches further clothed with many-coloured crusting species of sponges and tunicates.

Move but a short distance seawards to the deeper water of the channel, and the dredge brings up great scarlet and orange-coloured sea-fans (Gorgonids) and the whips of the related *Juncella*, together with a variety of sea-urchins and starfishes.[1] Still another short move to the muddy Bay of Balapur on the east side of Beyt Island and we come across multitudes of mud-dwellers of forms totally distinct from those of Aramra and Kiu, for we discovered here what appeared to be an extensive bed of window-pane oysters (*Placuna placenta*) and great quantities of a fine species of the brachiopod *Lingula*. On the sands at higher level on the littoral, great numbers of a burrowing Nemertine worm were met with, speckled on the dorsum to

[1] See illustrations to the Report on the Alcyonaria.

Photo by Vividha Kala Mandir, Baroda.] [*To face p. 6.*

A Memory of Samiani Island.

The names from left to right are :—

Upper Row : Dewan Bahadur V. M. Samarth and Mr. Hornell.

Lower Row : Mr. K. B. Pradhan, Vahivatdar of Dwarka ; Mr. Sunderlal, Executive Engineer, and Rao Bahadur Dr. K. V. Dhurandhar, Sanitary Commissioner of Baroda State.

match the coloration of its habitat, while at the junction of the muddy bottom with the sand and gravel of the higher zone at the north end of the bay, a giant anemone, *Discosoma* sp., was plentiful (Plate VIII.), together with a magnificent yellow species of the alcyonarian *Dendronephthya*—a cauliflower-like creature nearly related to the red coral of commerce. Even this does not exhaust the faunal variety

FIG. 2.—Lingula from Balapur Bay, showing the proportionate length of the muscular "stalk."

of the district—the flat-topped, surf-harried reef islets have their own distinctive animal associations—mostly free-moving creatures that know how and where to find refuge from the force of the breakers when heavy seas pound the reefs. Of such are crabs, crawfish and other crustaceans in fair variety and several species of octopus. Anemones allied to *Tealia* and *Sagartia* are numerous but inconspicuous, while beneath boulders a considerable diversity of molluscs, tunicates, worms, and fishes find refuge.

It was in clefts and under boulders near low-tide level around the margins of these reefs that we found the only pearl oysters (*M. vulgaris*) obtained during the investigation.

All the above mentioned localities received sufficient attention to permit their economic potentialities to be gauged; the faunistic results are given in detail in the "Narrative" of the work printed on other pages—we may therefore proceed now to a statement of the facts ascertained concerning economic questions and the conclusions derived therefrom, and then discuss in detail those which hold out any promise of successful development. We will treat the conclusions under the heads of pearl oysters, window-pane oysters, edible oysters, chanks and chank-fishing, and, lastly, sea-fishing and fish-curing.

PEARL OYSTERS.

That Pearl Oysters (*Margaritifera* sp.) exist on the coast of Okhamandal was well known prior to this inquiry, and several attempts had been made previously to ascertain if the establishment of a pearl fishery in the neighbourhood of Beyt be practicable. As the merchants of Dwarka transact considerable business with the ports of the Persian Gulf and the western shores of the Arabian Sea, the Okhamandal coast is frequented by Arab traders and by trading craft engaged in the export from Dwarka and Beyt of salt and of earthenware utensils. Many Arab sailors engage in pearl-fishing in the Gulf during the south-west monsoon and on several occasions some of these men have expressed the opinion that the Okhamandal coast is fitted for the establishment of a pearl fishery. What they meant was undoubtedly that the physical features of the shore, the depth of the water, and the general character of such seaweeds and animals that would come under their observation on the littoral and in the shallows are such as they associate in their minds with good pearling grounds in the Persian Gulf. Some Arabs are stated even to have averred that the west coast of Okhamandal "*abounds* with pearl oysters, especially to the west of the villages of Bhimrana and Mojab."[1] Another reason which favoured the presumption that a pearl fishery might be worked on this coast was the fact that further to the eastward along the southern shore of the Gulf of Kutch and within the limits of the State of Nawanagar or Jamnagar, pearl oysters yielding pearls of good quality are fished in considerable numbers. This pearl fishery is carried on under the control of the government of the Jam Sahib of Nawanagar; it has been known and famous for many years, and Mr. Samarth mentions that of so much account was it in the days of the Emperor Aurangzeb, that Nawanagar was made Khalsa Sarkar under the name of Islampur, the Jam being continued

[1] These facts are derived from a report by Mr. Samarth, the Sar Subha of Baroda, kindly communicated to me.

as ruler. "And the Jam forbore to work these fisheries for fear, lest if their great value should be known to the Emperor, his territory might be permanently confiscated"!

That some of the best of the Jamnagar pearl-fishing ground is situated on tide-washed reefs a few miles to the east of Beyt was a fact holding out distinct promise to the Okhamandal officials; accordingly, the services of two Arab divers were secured for two months in the autumn of 1894 (about October), but without any success, the season being stated to be unfavourable.

Subsequently two Nawanagar pearl fishers who had settled in Dwarka were induced to make a fresh attempt. They did succeed in finding some pearl oysters, and from these about seventy-nine pearls were obtained, of an aggregate value of Rs. 58-11-0. Three other pearls were found about the same time, one of which was valued at Rs. 30, the others at 8 annas and 6 pies respectively. They were of the same general quality as the average of those fished in Jamnagar. This particular attempt was then abandoned, as it was considered undesirable at that stage to spend more money on investigation, principally on account of the great difficulty experienced in obtaining men having suitable knowledge of the work.

In view of this obstacle to local effort, I was desired by the Baroda Government to engage in Ceylon a small staff of divers to accompany me to Dwarka and take part in the work of inspection. I therefore took with me three of the best Tamil divers I was acquainted with, men capable of diving and working at a depth of ten fathoms, and as far as possible we utilised their services on every suitable occasion. Unfortunately, the only season when the western coast of Okhamandal can be examined is during the cold season, when the north-east monsoon is on; as a consequence the temperature of the sea was low, and the discomfort of this to naked divers was so intensified by chilly winds that the time devoted to diving was much curtailed on many days. A combination of diving, dredging, and wading at low water proved sufficient to provide the necessary data to enable us to settle the question at issue definitely and finally.

The facts ascertained regarding the different sections of the coast may be summarised as follows:—

Western Coast.—No living pearl oysters were found anywhere along the western coast of Okhamandal, neither were there found any dead shells—not even the veriest scrap of one.

Right along this shore, from Dwarka northwards to Okha Point, unmistakable signs were everywhere manifest of the great force and violence of wave-action experienced during the south-west monsoon. Just north of Dwarka headland the tidal or littoral plateau is of great width and remarkably level. Even a tyro can see how the plateau owes its origin to the undermining and disintegrating action of the heavy rollers which at high tide during the monsoon break at the base of the cliffs with terrific force. The sea is gradually eating into the land all along this coast, forming a wide

tide-washed fringing plateau wherever the sea is margined by hard strata. (Plates III. and V.)

The dearth of life over this littoral plateau is extraordinary ; nowhere else have I seen so bare an expanse of sea-washed rock. Scarcely a limpet is to be found, and seaweeds are few and inconspicuous. Only here and there in a pool exceptionally well protected do some forms of life flourish. (Plate VI.)

Beyond low-tide level, along the rocky portions of the coast, the littoral is margined by a considerable width of sea-worn, rounded boulders, torn originally from the coast cliffs, and rolled about on the littoral plateau till at last they have found their way to a depth where they suffer little disturbance. Among these boulders I found considerable wealth of life at the time of my visit (December-January), when they were swathed in a dense growth of seaweeds of several species. I was told that towards or at the onset of the south-west monsoon, this growth dies down. Anyway, with weed of such density it is a practical impossibility for divers to exercise selection in what they pick up, and to find oysters—even if they were there—is not possible. It would be even as looking for a needle in the proverbial bundle of straw. Besides this, work by naked divers during the winter season is not commercially practicable on account of the coldness of air and water—the air more especially, as the men feel the chilliness of the air most acutely during the intervals between diving. Even lusty Arabs will not face the hardships of pearl-diving in the winter season in the Persian Gulf; so we may at once rule out the possibility of carrying on a fishery by means of naked divers on the west coast of Okha during the cold months of the north-east monsoon. The violence of the sea during the rest of the year—the warm months when pearling goes on merrily in the quieter waters of the Persian Gulf—with even greater force precludes pearl-fishing operations on the ocean coast of Okha at that season.

With naked divers ruled out, the only alternatives, and those too, available only during the north-east monsoon, are fishing by mechanical means (dredging), and by divers with diving suits and pumps. Neither is feasible, the former by reason of the unevenness of the ground, and the latter partly for the same reason, and partly because of the smothering growth of seaweeds.

I am satisfied that if oysters did exist in quantity on this rough and uneven bottom, very great difficulties would be experienced in fishing them. I am, however, equally satisfied that pearl oysters do not and cannot exist in this particular locality in any number sufficient to make them worth a search. The bottom is too rugged to suit pearl oysters, which, except in such an unusual instance as the sheltered Jamnagar reefs, require fairly level bottom if we hope to find them in really paying quantities, *i.e.*, in aggregated masses or "beds," in contradistinction to the isolated habit characteristic of the Kutch or Jamnagar pearl oysters. (*Note.*—As will be seen further on, the Kutch pearl oyster is the same species as that of Ceylon, being the small thin-shelled *Margaritifera vulgaris*, which is normally or typically gregarious.)

Northern Coast.—As already noticed, the shore of Okhamandal washed by the Gulf of Kutch is much more varied in physical and faunistic characters than is the western or ocean coast. According to the different physical features of the littoral, we may conveniently treat the various sections under heads, as follows:—

(*a*) Adatra coast facing Beyt Island,

(*b*) The steep western and southern shores of Beyt Island,

(*c*) The rocky islets in Beyt Harbour,

(*d*) Aramra and Kiu shores,

(*e*) Balapur and Rann Bays,

(*f*) Flat-surfaced reefs submerged at high tide—Chindi, Hanuman Dandi, Mangunda, Borio, &c.

Fig. 3.—Types of Porites coral growth, Adatra littoral.

(*a*) *Adatra.*—This locality is that part of the Okha peninsula north of Aramra Creek. It is a low-lying tableland of gritty coral limestone. From a point opposite the town of Beyt and thence southwards towards Aramra Creek, the eastern side is fringed with an extensive stretch of reef-like littoral gradually sloping to extreme low-water mark. The tide-race through the narrow channel of Beyt Harbour furnishes ample supply of food particles, and as this end of the harbour is kept free from mud

the flat littoral of Adatra is very rich in organisms that love the rush and swirl of tides and highly oxygenated water. Massive corals (*Porites, Turbinaria,* and astræids) and great fleshy alcyonarians (*Sarcophyton*) flourish in great luxuriance and, strange to say, bear occasional exposure to the air without ill consequences at the times of great spring tides. Madrepores (branched corals) were conspicuous by their absence. Little weed grew here except near low-tide level, and several dead shells of fully grown pearl oysters (*M. vulgaris*) were found. The Vahivatdar was also able to assure me that live oysters have been found here to his knowledge. Certainly the place is quite suited to give them foothold, but as the reef slopes off rapidly from low-water level into the deep, gravelly channel of the harbour, and as the range of pearl oysters does not extend far above low tide, the reef at best can support them only in extremely limited number.

(*b*) *North and south of the town of Beyt* and also along the south coast of the island, the land rises abruptly from the sea into cliffs of fifty to sixty feet in height. The sea bottom along these cliffs is very uneven and is not suitable for the growth of oysters. In many places there is a great tangle of sea-fans and sea-whips (Gorgonids), while the current on the bottom is usually very strong. Every time we used the dredge we had trouble; it was continually fouling some obstruction so that even if there are pearl oysters here (we saw not a trace of any) they could not be fished save by pump divers, at a cost which would be prohibitive.

(*c*) *The rocky islets and small reefs in Beyt Harbour.*—On some of these, as for example the Dhed Mora, occasional pearl-oyster spat may settle in the zone near low water. At the season when I was there, seaweed growth was so rank at this and the next lower horizons that it was impossible to search effectively for *stray* individuals. Had oysters been present in any fishable quantity—in any number adequate to make fishing remunerative—the search was sufficiently effective to have revealed some. The nature of the ground, boulders of all sizes piled up round the bases of these rocky islets, is quite against the presence of any fair quantity under the best conditions of spat-fall and immunity from enemies.

(*d*) *Aramra and Kiu.*—As mentioned incidentally once before, these localities are covered in the main with a varying thickness of soft mud. Pearl oysters cannot possibly exist there, though in the higher portions of Aramra Creek there is a "hard" which is well suited to the cultivation of the edible oyster. Of this more will be said on another page.

(*e*) *Balapur and Rann Bays.*—The bottom in these bays is a uniform expanse of flat mud tenanted by beds of window-pane oysters, by *Lingula,* a suberitid sponge and other lovers of the mud. These localities share the disabilities of Aramra and Kiu.

(*f*) *The flat-surfaced reefs.*—The principal of these consist of Chindi, Borio, and Mangunda, the first due north of Beyt Island, the two latter east of Poshetra. Hanuman Dandi may also be grouped here, albeit it differs in being still in physical connection with Beyt Island.

The following particulars of Borio and Mangunda taken from the rough field notes made on the spot will indicate the physical and faunistic features common within close limits to the majority of the reefs which are dotted along the southern shore of the Gulf of Kutch for a considerable distance eastward of Okha Point and Beyt.

Borio reef or kharaba was found to resemble the eastern or more sheltered portion of Chindi reef fairly closely, but animal life on Borio is much richer and more diversified. A raised gravel bank on one edge of these reefs is a characteristic feature and seldom or never wanting. At Chindi such a bank is found on the south side, but on Borio and the neighbouring Mangunda it has a north-east aspect, a difference due to the set of the tide, which runs very strong between these reefs.

The surface of Borio is nearly dead level, and represents a plane of marine denudation, the sea having cut its way entirely across the original islet, so that no point remains unsubmerged at high tide.

In shallow hollows at the north-east end were many finely grown corals, massive *Porites*, dome-topped astræids, a thin brittle species, and some others, a greater diversity than anything before seen in the district.

The higher level, say six to nine inches above these pools, is gravelly, made up largely of worn fragments of madrepore branches, with immense quantities of *Vermetus*, a strange mollusc forming sinuous calcareous tubes attached to the pebbles. A drab-yellow anemone (*Tealia* sp.) lives here in profusion with a few of another anemone, the giant *Discosoma*, characterised by a multitude of tiny knobbed tentacles set like velvet pile over the widely spread disc (Plate VIII. fig. 1).

In the shallows the same anemones occur, together with a third with column well sunk in the gravel, and not unlike a *Sagartia* but with short pinnate processes on the tentacles. Several of the large wedge-shaped bivalve *Pinna* were found here, and also the complete shell of a pearl oyster of the same species as that of Ceylon (*M. vulgaris*), and fragments of others. The complete shell belonged to an individual apparently recently dead and aged about two and a half years. A fragment of another shell was picked up close by.

Several octopus—well-known enemies of bivalves such as the pearl oyster—were seen, and are, I fear, fairly common.

On the north-east fringe of the reef few algæ were seen; on the south side they were abundant, making the search for pearl oysters very difficult. A large number

of loose blocks of dead coral are present along the southern portion of Borio and these give shelter to numbers of crabs, small fishes, and crusting sponges. Large zoanthids were not uncommon associated with large fleshy alcyonarians (*Sarcophyton*).

The formation of Mangunda reef was found very much like that of Borio, rich locally in corals, anemones, octopus, and, at extreme low water, fine colonies of a cauliflower-like pale orange *Dendronephthya* (*D. brevirama*).

On the higher level in the centre of the reef, the small coral fragments forming the surface are infested with *Vermetus* tubes and with multitudes of brood edible oysters (*Ostrea*) whose sharp edges make walking barefoot most dangerous.

In the shallows towards Borio, a profusion of red algæ of several species was present.

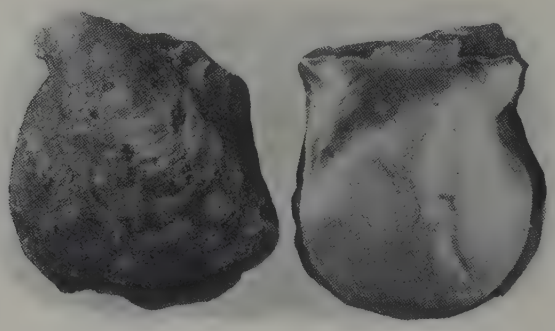


Fig. 4.—Inner and outer view of the valves of a Pearl Oyster (*M. vulgaris*) from the Gulf of Kutch.

It was on Mangunda that we at last found the pearl oyster alive—a single individual at extreme low water attached to the overhanging side of a boulder. It was about eighteen months old, very fat and in an excellent condition of health. Besides this not less than ten dead shells were found of an age, when living, of from one and a half to five years. All were of the Ceylon species, and as the other live and dead oysters found at Pagar Kada and Adatra were similar, it would seem that the Kutch pearl oysters all belong to *M. vulgaris*.

On another day a visit was paid to Pagar Kada, a reef of much greater size than either Borio or Mangunda. In many respects it is a reef of special interest for the reason that on account of its large area some parts of the central region have peculiar physical characteristics. These, however, need not be particularised here, as our examination of this reef confirmed the conclusion come to from a study of Borio and Mangunda, that the habitat of pearl oysters in these waters

is limited to the *peripheral* region—to that zone which is uncovered, and then only partially, at the times of exceptionally great spring tides—tides which occur but seldom in the course of each year. This zone forming the pearl oyster habitat is the equivalent of the European laminarian zone. On Pagar Kada we saw evidence of the presence of pearl oysters in this zone in greater numbers than on any other reef examined, both in regard to living individuals and dead shells. Unfortunately, Pagar Kada, although geographically belonging to Okhamandal, is claimed by Jamnagar on the ground of prescriptive rights (pearl fishery rights I presume they are), and the Courts have decided in favour of this contention.

Summing up the facts ascertained regarding the conditions under which pearl oysters live in this district, we find that they occur solely in that zone which marks the low-tide seaward fringe of the shore reefs of Adatra, Poshetra, Hanuman Dandi, of the isolated reefs of Chindi, Borio and Mangunda, all submerged at high tide, and of the rocky islets in Beyt Harbour.

The most valuable of these (if we can use such an expression when the oysters occur so sparsely) are the reefs of Borio, Mangunda, and Adatra; Chindi and Hanuman Dandi appear less favourable as the habitat of pearl oysters.

Now comes the consideration as to whether anything can be done to establish a remunerative oyster fishery in the district. We see that pearl oysters do live there naturally, and that they thrive and even produce pearls—one of the three found by us contained a fair-sized pearl. We know, too, that a small pearl fishery has existed on the co-terminous coast of Jamnagar, where similar natural conditions prevail; therefore it will be useful at this point to see how this fishery is being carried on at the present day, and to see if it has further light to throw on our own problem.

The rules laid down for the conduct of the Jamnagar fishery show the industry to be one of great antiquity, and one regulated by rules as quaint as they are unique.

The essential points are as follows:—

(*a*) The fishery is carried on under Government control and supervision as a monopoly of the State.

(*b*) The pearl fishers are not paid in wages for their labour, receiving instead a specified proportion of the value of the pearls they may find, partly in cash, partly in kind.

(*c*) All pearl fishers are licensed by families, and no one may obtain these licences except fishermen of specified villages. (*Note.*—This gives the shore-dwelling villagers a direct and *hereditary* interest in the fishery, and is a regulation so excellent that it might with advantage be adopted in modified form elsewhere.)

(*d*) The pearl fishery season is limited to the hot weather season, beginning in June. It is not carried on daily, but only on the dates of the greater spring tides, when the lowest levels of the littoral may be expected to be uncovered at low tide.

(*e*) Before that date a day for the issue of licences is appointed, those men who are registered as pearl fishers in ten shore villages being alone notified.

(*f*) The licensees then form themselves into fishing groups or parties, and are allotted one or more supervising officers of the State, according to the number forming the party. A Wagher patel has also to accompany each party.

(*g*) Pearl fisher parties may fish anywhere they choose, but the members of each party must keep together that supervision may be efficient.

(*h*) On the days selected for pearl-fishing the fishers assemble at the house of their supervising officer, who then accompanies them. They pursue the fishing by wading. When necessary to use boats to reach the fishing grounds these are provided free by the chief customs officer.

(*i*) At the end of each day's work all oysters collected have to be opened in the presence of an official, who notes the number of pearls obtained by each fisherman, and provides him with a numbered cloth in which to wrap them. These little bags are then dropped into a sealed box, where they accumulate till the end of the fishery.

(*j*) With the close of the season all boxes are conveyed to the Jamnagar Treasury where they are opened and the bags belonging to each fisher sorted out from the others and their contents valued by experts.

(*k*) Finally each man receives $\frac{1}{5}$ the value of his catch in cash, $\frac{1}{40}$ in cloth, and $\frac{1}{20}$ (already received) in food, while two prizes are given to the two villages producing the most valuable collections of pearls.

From the foregoing and from the knowledge acquired during the examination of the Beyt and Poshetra reefs, we see that at its best, along the lengthy sea frontage of Jamnagar, off which lie numbers of productive reefs of much greater circuit than any within the limits of Okhamandal, the pearl fishery of the Gulf of Kutch is what may be termed a village industry. No beds of oysters occur anywhere within the district. The oysters occur sparsely, scattered singly along a narrow fringe bordering the reefs and accessible only on the dates of great spring tides during the warm period from June to September—a very limited fishing season.

In view of these difficult conditions, I do not think the method of actual fishing pursued can be improved greatly, as several practical obstacles preclude the employment of naked divers—chiefly the difficulty and excessive labour that are involved in making a search under water for oysters so sparsely scattered as they are here; the great force of the currents along the margins of the reefs also stands in the way of successful diving (my divers complained greatly of this and often said they could not keep their feet on the bottom). The employment of pump divers is even less feasible; the cost would be quite disproportionate to the returns, more especially as the mother-of-pearl of the shells is of very low value.

But while a village industry in pearl-fishing is moderately successful in Jamnagar, there is no possibility of introducing similar methods in Okhamandal, because the suitable shore-line there is far too restricted to furnish more than a few dozen oysters even if large numbers of men be employed on all available days. It is not as though the whole shore-line is of oyster-bearing value; much more than half is unsuitable.

Nature unaided fails us in this matter; it may be then asked whether science cannot help—whether some form of culture might not be successfully introduced.

Reluctantly I must answer in the negative so far as present methods go. In the case of *M. vulgaris*, the small pearl oyster living there, the shell is of such little value, so thin and convex, that it is fished for the pearls that may be contained and not for its shell. But pearl-bearers form always so very small a proportion of the catch that if we were to cultivate them in cases or otherwise we should find so many unproductive of pearls that the expenses of spat-collection, supervision, and upkeep would entail certain failure under such conditions as we have around Beyt. Were there beds of natural spat available for transplantation in the neighbourhood, the attempt indeed might be made, not otherwise.

Were we able, however, to control and induce the production of fine quality pearls in any given oysters—I do not refer to the imperfect or attached pearls produced in Japanese oysters on the lines of the ancient Chinese plan—then it might be practicable to carry on such special culture at several localities in Beyt Harbour, seeing that the strong tides experienced there are favourable to the rapid growth and maturing of the oysters laid down there. But such a proposition is one requiring a combination of skill and organisation not at present available and would be a commercial enterprise unsuitable for a Government to undertake.

The most that I can suggest is that for the present the collection of pearl oysters be leased out, if possible in conjunction with that of chanks—that is, that one lease should cover both products, because if they were leased separately there would probably be friction between the respective renters; the chank renter and the pearl oyster renter would naturally fear invasion of their respective rights. As to restrictive regulations if this proposal be acted upon, I do not consider the enactment of a size limit is practicable or would be of any value. But the reservation in rotation of different sections of the coast for stated periods during which all fishing therein for pearl oysters and chanks shall be forbidden, is both feasible and likely to result in material benefit to both fisheries.

Under the heading of "Summary of Recommendations" I shall take up this proposition in detail.

CHANK-FISHING.

The chank or shank (*Turbinella pyrum*) is a shell as characteristic historically of Okhamandal as the pearl oyster is of Jamnagar, and although neither this nor the sections dealing with other marine products which follow come within the terms of reference of my investigation, I trust that the following notes of what I learned and the impressions received will be approved and prove useful.

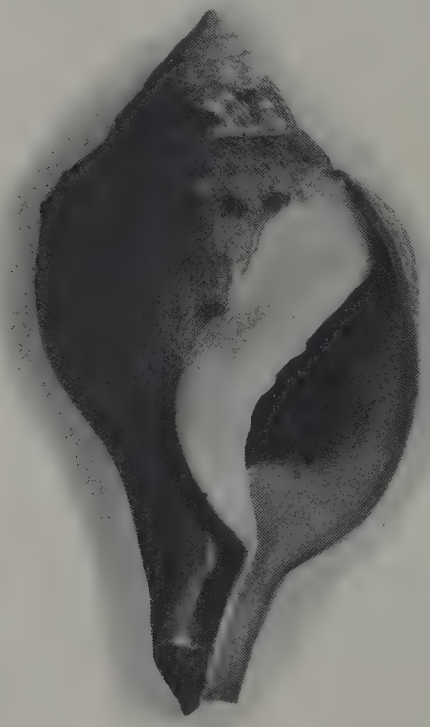


FIG. 5.—An adult chank from the Adatra reefs, Beyt Harbour. $\times \frac{2}{3}$.

At many places along the coast from Dwarka to Beyt the chank occurs in sufficient abundance to make chank-fishing a small local industry. Since Samvat 1918 (A.D. 1861) the monopoly of the fishery has vested in the Baroda Government. Till A.D. 1893 the authorities combined two systems of administration, renting out to the highest bidder the chank fishery in the Island of Beyt, while the chank beds of the mainland (Aramra and Meeta Bundar) were worked by individually licensed fishermen, who paid Rs. 3 each for the privilege. Since the date

named the lease of the whole fishery, mainland as well as insular, has been put up to tender, and is now fished by men either employed directly by the renter or under sub-licence from him. The renter is the only person in the district entitled to vend chanks, and the places where sale may take place are limited to three—Beyt, Aramra and Gopi.

The annual revenue to Government for the eight years following their assumption of fishery control was respectively as follows, viz. :—

Samvat	1918 and 1919 ...	...	...	Rs.	191	10	8
,,	1920 ...	...	...		55	0	0
,,	1921 ...	...	...		20	0	0
,,	1922 ...	...	...		5	0	0
,,	1923 ...	...	...		65	0	0
,,	1924 ...	...	...		90	0	0
,,	1925 ...	...	...		110	0	0
	Total for 8 years ...	...		Rs.	536 ,,	10 ,,	8

an average of say Rs. 67 per annum.

Comparing this with recent results, we find that the rentals at which the fishery as a whole was leased out during the ten years ending 1906 were as follows :—

1896–1897	...	...	...	...	Rs.	96	0	0
1897–1898	...	...	...	...		160	0	0
1898–1899	...	...	...	...		160	0	0
1899–1900	...	...	...	...		97	0	0
1900–1901	...	...	...	...		81	4	0
1901–1902 to 1905–1906	five years		...	...		755	0	0
	A total for 10 years of			...	Rs.	1349 ,,	4 ,,	0

which gives an average of Rs. 134-14-10 per annum, a sum comparing very favourably with that obtained at the beginning of Government administration.

It would be interesting and useful to learn if this rise in the value of the fishery is due to increase in the numbers caught, or whether to a rise in price. There appear to be no data on the subject, as the lessee, who alone could furnish them, can hardly be expected to supply such a return. I am inclined to the opinion that the cause is more likely to be due to increase in the selling price, seeing that the customers for this strange article of commerce are confined to Hindu pilgrims visiting the holy places of Beyt and Dwarka, who have largely increased of recent years since regular steam communication was established between Dwarka and the ports of Sind, Kutch,

Kattiawar, and Bombay ; the opening of a railway to Nawanagar, only some fifty miles distant, has also had a favourable influence in causing an increase in the pilgrim traffic, and this in turn has probably entailed a rise in the retail value of the chanks purchased as charms and holy souvenirs of a memorable pilgrimage.

We come now to a consideration of whether it is necessary or desirable to take any steps to safeguard the well-being of this industry, and whether it is possible to do anything to render it more productive.

In the first place we have to recognise the great limitation of the area where the fishery is carried on. The habitat of the chank is a peculiar sandy bottom known to the Tamil chank fishers of the Gulf of Mannar as *puchchi manal* or "insect-sand," containing such an amount of mud and organic matter as forms it a suitable home for the sea-worms whereon the chanks feed. This haunt of the chank is found at comparatively few places on the Okhamandal coast, the principal being the sandy shore north of Kutchegad, the sands of Soso Bhara (esteemed the best on the west coast), the bay between Okha and Vamiani Points, the coast of Adatra facing Beyt Island, and Hanuman Dandi at the north of Beyt Island. A few are also taken on a part of Chindi reef and on some of the banks in Beyt Harbour; some also at Borio and Mangunda. All told the chank grounds suffer from the unalterable disadvantage of possessing extremely limited area which in all probability cannot support any large increase in the number of chanks living thereon. As no considerable increase in the revenue can be hoped for on account of this limiting factor, any measures to be taken must be equally limited financially.

If we turn to the great chank fishery of South India, we find that the sole limitation imposed by the authorities on the fishermen, is that they shall return to the sea any chank found that will pass through a gauge hole having a diameter of two and three-eighths inches, and this is a rule which, if adopted in the Okhamandal fishery, in my opinion would tend to benefit the industry, as it would help to conserve the chanks till they reach maturity and have an opportunity to breed and raise up seed unto themselves. It would go far to counteract any possible ill-effects arising from overfishing, which the payment of a high rental and a brisk demand for the shells is bound to induce. Such latter factors are, I fear, likely to result eventually in a more or less severe depletion of the beds. Of course, the selling of undersized or immature chanks would also have to be made a punishable offence. So I recommend the partial protection of chanks when next the fishery be leased by the insertion of a condition (with proper penalties for infraction) that no chanks be fished less than two and a quarter inches in diameter and that gauges of this size be kept by the local officials at the fishery and sale villages. If enacted, it must be impressed on the fishermen that these undersized shells be returned to the sea near the chank bed as soon as possible after the close of the day's fishing—we cannot expect each man to carry a gauge with him, and

probably it will be found convenient to defer the measuring till the men gather together at the end of the day.

It will be noted that I suggest a smaller gauge than that in use in South India; it is better to err on the lenient side till further experience be obtained. The benefit to be derived from this procedure should be clearly explained to the men in order to gain their goodwill in carrying out the regulation.

Close Season.—If a size limit as above be enforced, no special close season need be enacted, as the fact that fishing can be carried on with advantage only on the dates of the great spring tides constitutes a natural close time sufficiently protective to require

FIGS. 6 and 7.—Half-grown chanks (*Turbinella pyrum*) from Adatra reefs, Beyt Harbour.

no artificial extension. It may, however, be useful to close the different sections of the coast in rotation for limited periods.

Culture.—Any form of culture necessarily demands the attention of an officer with at least an elementary training in fishery science on the culture side. Current conditions preclude, I fear, the provision of such an officer; but as there is a likelihood in the near future that opportunities may be available for natives of India to receive training at Government fishery stations on the Madras coast, I propose to suggest how, at small expense, were the necessary oversight provided, simple cultural methods may be tried with a view to increase the yield of chanks and prevent any fear of a depletion of the beds.

I would propose that advantage be taken of the fact that the female chank deposits her ova in large capsules six to ten inches long, formed of a tough, parchment-like substance and having the form of a twisted and corrugated ram's horn. They are unmistakable when once seen, and are internally divided by a series of transverse (horizontal) walls agreeing with the number of grooves on the exterior. In the compartments thus formed eight to ten young chanks develop from eggs. They remain to quite an advanced stage within the capsule, breaking out only when they approach a length of about half an inch. The larger capsules may contain a total of 150 to 230 young of a size fit to begin a free life.

If operations be decided upon, means should be taken, by reward or otherwise, to obtain a number of these capsules and transfer them to a small pound or enclosure near low-water limit and on a bottom of suitable chank sand. Here they would be kept till the young chanks escape from the capsule, when they may be allowed to wander freely within the enclosure in search of food. Care would have to be taken that the netting or palisading of the pound be fine enough to prevent the young chanks making their way out. It would also be desirable to provide some shelter, in the shape of seaweeds, within the pound that the young chanks may crawl beneath the fronds if they wish. Later on, as experience be gained, a further step may be taken by enclosing a number of mature chanks within the pound with a view to obtaining a regular supply of egg-capsules. It must be understood, however, that these suggestions are tentative; no attempts so far have been made to subject chanks to cultural methods—probably experience will necessitate considerable modification and elaboration of the operations suggested. The first point to ascertain will be the spawning-time of chanks on the Okhamandal coast; we have no information thereon at present.

EDIBLE OYSTERS.

Two species of *Ostrea*, the edible oyster, occur in Okhamandal, namely—*O. cristagalli*, L. and (probably) *O. cucullata*, Born. The former, which covers the rocks near high-water limit at Poshetra Point in vast numbers, is unfortunately of little economic value on account of its comparatively small size and very irregular growth; the second species, as seen in samples from Aramra Creek and from Poshetra Point, grows to a good size and is of most excellent flavour.

Hitherto the demand and taste for edible oysters in India has been extremely restricted and usually in local demand only, but may be expected to increase rapidly when once regular supplies are available, seeing how nutritious and palatable this mollusc is.

Oyster culture has two important initial advantages—the ease and low expense at which it may be carried on, and the endurance shown by oysters during transport; live oysters are successfully sent in large quantities from America to Europe headed

up in barrels, and a considerable proportion are laid down in English waters either to fatten and improve in quality, or to await a better market.

When abundant they may be canned for export or their flesh dried for despatch to China where there is a large and steady demand for such and similar delicacies.

The industry in Okhamandal is, however, too limited by restricted area to permit of the latter uses, which necessitate both a very extensive and very cheap supply. If anything be done, it must be, as at Karachi, in the supply to inland towns of high class live shellfish. This can be effected only when means of rapid transport be available, which will come when a railway be built from Aramra to Nawanagar, and when a fishery expert be available to initiate methods and demonstrate how simple is the procedure to be followed and, it is hoped, how profitable the results obtainable.

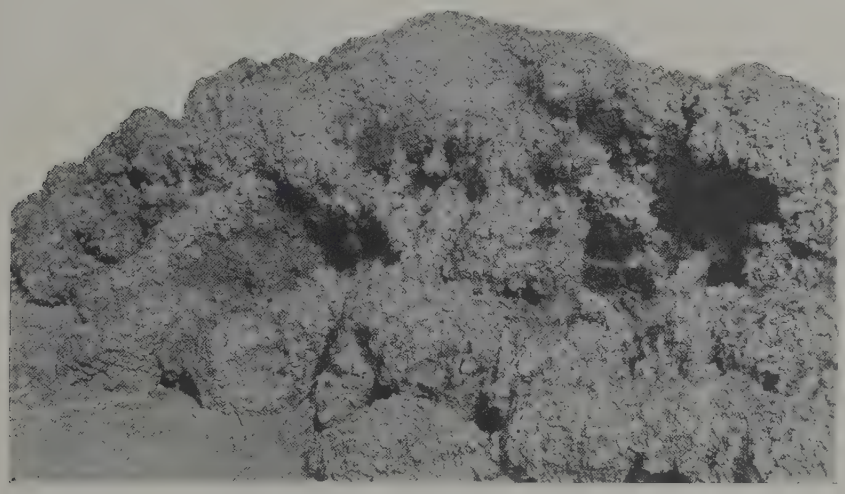


FIG. 8.—Oyster rocks between tide-marks at Poshetra Point. The species is *O. crista-galli.*

Aramra Creek is an ideal situation for oyster cultivation. The area is fairly extensive and is favoured with exceptionally great abundance of suitable oyster food (diatoms and algal spores were profuse in the plankton taken there), suitable bottom exposed over the whole area at certain spring tides, and lastly, complete protection from rough seas.

In many ways Aramra Creek has a close resemblance to Brightlingsea Creek in Essex, famous alike to oyster culturist and yachtsman. The advantages are, however, with Aramra; the area of hard bottom composed of shingle set in a soft clay or compact mud, is greater, and forms an admirable "laying ground" requiring little improvement by cleaning and cultching. It is here that oysters are now found naturally in fine condition. Others, again, are found towards the head of the creek attached to the roots of mangroves lining the banks. It would be a very

simple operation to plant numbers of stakes in the muddy bottom at the lower end of the creek, or to lay out piles of suitably coated tiles at the spawning season (yet to be ascertained) to form spat collectors; the spat so collected, some months later would be removed from the stakes or tiles and laid out on prepared (cleaned) gravelly bottom and left there to mature, the bottom being carefully tended the while to keep down seaweeds and destroy any enemies of the oyster. Variations and improvements in details would evolve with experience.

The initial experiments to prove that spat-collection and oyster-laying may be successfully carried on should be conducted by Government. If satisfactory results be obtained it is to be hoped that local people would then be induced to come forward and take up sections of the creek on lease from the Government at a purely nominal rental till such time as the industry may be established on a remunerative and stable basis. After that it would be for the administration to decide whether the industry could bear the payment of actual rent or whether it be more desirable to be satisfied with an indirect revenue return such as would accrue through the increased employment provided and the greater prosperity induced in the district by the new industry.

I may mention here that an extensive and profitable trade was carried on until recently at Karachi in edible oysters obtained from the Sind coast. Some years ago it was brought to the notice of the authorities that, owing to the improvident methods of the oyster fishers, the oyster beds in Karachi and its vicinity were being rapidly exhausted. To stay the progress of depletion and restore the prosperity of the beds certain regulations were then adopted for the better control of the industry. These protective measures appear to have proved unsuitable or insufficient, as the condition of the beds is now (1908) in an unsatisfactory condition, the beds being practically depleted. The rules which have thus failed in their object consisted in :—

(1) The observance of a close season from 16th April to 1st October in each year.

(2) The licensing of fishermen engaged in collecting oysters for market.

(3) Prohibition against the removal of oysters less than two inches or more than six inches in diameter.

(4) Closure of the creeks by compartments to oyster-fishing in rotation for periods of two years.

THE WINDOW-PANE OYSTER.

This mollusc, *Placuna placenta*, provides a fishing industry of local importance in four widely separated localities in eastern seas, to wit, Sind, Ceylon, Borneo and the Dutch Indies. Pearls of inferior quality are yielded in some quantity, while the flat, translucent shell itself is used in China and Indo-China and the Philippines as a substitute for glass in the glazing of windows, whence the popular name. Formerly

this latter use was employed also in the Portuguese possessions along the west coast of India, but at the present day the Indian fishery in the creeks of Sind and that near Trincomalee in Ceylon are pursued solely for the pearls produced. The comparatively poor quality of these is gauged by the recognised standard market value, Rs. 15 per tola, which prevails both in Sind and Ceylon. Although the object of a recognised pearl fishery in Sind since 1837, when beds of window-pane oysters were fished for the first time by the Mirs of Sind, no official knowledge either of the pearl value of these shells or indeed of their existence in the Okhamandal district seems to have existed prior to the recent investigation. My attention was first drawn to the probability of their presence by seeing a large shell in a natural history collection at the Public Library in Beyt. Subsequently large numbers of well-grown living individuals were found towards low-water level in Balapur Bay, while later, quantities of brood and of half-grown shells were obtained by the dredge and by divers from shallow water, one to one and a half fathoms, in Rann Bay, a wide muddy indentation in the coast-line at the north end of the Okha Rann. Enough was seen to demonstrate the presence of well-stocked beds both in Balapur and Rann Bays. Dissection shows that mature individuals contain pearls in average abundance, so we are fully justified in believing that in some years sufficiently large beds of these oysters arrive at maturity to provide a remunerative fishery if there be present the means for carrying one on. Herein lies the crux ; either oyster dredges specially adapted for work over soft mud must be employed, necessitating, too, the use of a shallow draught steam-launch or, preferably, a motor-boat, or a supply of divers accustomed to diving in shallow water must be obtained. In some respects the latter plan has considerable advantages—there is no initial capital expenditure, no heavy costs in upkeep during periods when the boats and gear be not employed, whereas if some of the villagers on the coast could be induced to practise diving they would add to their means of livelihood, be of inestimable service in the fishing of these window-pane oysters when required, and be available for any under-water work, such as the cleaning of ships' bottoms and the recovery of coal lost overboard, should Beyt ever become an important seaport, as Nature surely intended it to be.

In such shallow water as that of Balapur and Rann Bays, diving in the warm days from June to August should be an art easily taught to the lads of the shore villages. If Government encouragement were to be given by the offer of a few prizes to those who attain a certain proficiency, or by other means which the local officials may adjudge desirable, the hardier and more enterprising lads might be induced to give more thought to the sea as a life-calling than they do at present. Such lads, if they can be taught diving and swimming, would eventually furnish the personnel necessary should sea-fishing ever be developed to a considerable extent on the Okha coast. Of this more will be said in the following section.

In neighbouring Sind, the window-pane oyster industry has had a chequered

history. Some years have been moderately profitable to the lessees, while others have proved barren. The lean years may occur because of several factors, but it is probable that the chief cause is to be traced to reckless and wasteful methods of fishing, especially to the wholesale destruction of immature oysters. In Ceylon I have seen huge piles of shells, remnants of former fisheries, of which quite a large proportion were too young to be of any real value. To obtain, say, a few pies worth of pearls a whole thousand of young oysters are often destroyed, which if left to maturity would yield pearls ten- and twenty-fold or more in value. This, too, leaves out of account the fact that such destruction, taking place before full sexual maturity is reached, must militate most materially against the repopulation of the beds with new generations.

Should the window-pane oyster become the object of a fishery in Okhamandal, I recommend strongly that a regulation be made and enforced strictly enjoining the fishermen to put back upon the sea bottom, *convex side downwards*, all oysters less than four inches and a half in longest diameter. Very few pearls are present in oysters under this size, so no material loss will be caused to the fishermen or the lessee, and a valuable step towards ensuring the continued well-being of the beds will be effected. No necessity is likely to arise for a long time to establish a breeding reserve, provided size limit be enforced, as every muddy bay along the coast of the Gulf of Kutch has its beds of these oysters, capable of restocking the Okha bays should the stock there become depleted. Until all such bays be the subject of a similar fishery—a contingency most unlikely—the oysters therein may be looked upon as constituting natural breeding reserves for the whole neighbourhood.

On account of the chill winds of winter, the season for fishing is indicated as the warm period from May to September as a maximum; June, July and August will probably be found the most suitable months for the work. The rest of the year may be considered as a natural close season.

In Sind and in Ceylon the beds are rented out for periods of three to five years; if it be possible the same system will probably be found the most suitable for Okhamandal also, as departmental working is necessarily expensive in the case of a small and intermittent industry such as this must be under the most favourable circumstances.

Mr. Pradhan suggested the possibility of utilising the shells in button-making. This is worthy of attention, but I fear cannot be a success unless some method of hardening the shell be discovered—the shell is too soft and partakes too much of the nature of slab mica in its natural condition to withstand abrasion, a quality button material must possess to command extensive employment. Possibly permeation by some fluid cement might effect this object. I hope to experiment on such lines before long.

SEA-FISHING AND FISH-CURING.

What I trust may prove the most valuable and far-reaching result of my inquiry was to find that though fishes of valuable food species abound in great numbers both on the northern and western coasts of Okhamandal no fishing industry exists. I believe I am correct in saying that not a single fishing boat nor one fixed engine for trapping fish exists within the territory.

On entering upon my mission the possibility of visiting a long stretch of varied coast-line, where sea-fishing is non-existent was too improbable to enter into my thoughts and as this question was not included as a subject of my deputation I took neither lines nor nets with me; as a consequence I cannot furnish any details touching the relative abundance of the more important fishes nor can I say much as to their species.

What I can state with certainty—facts based almost entirely on notes of the species caught specially by the Samiani lighthouse-keeper and on a few fishes caught or seen during the general investigation—is :—

(*a*) That valuable flat-fishes of the genus *Synaptura* are to be had in Balapur Bay on the coast side of Beyt Island. This fish is closely allied to the true sole and is, I believe, fairly abundant.

(*b*) That the group of fishes generally termed "Rock-fishes" from the preference they show to rocky bottom, are very abundant in the western section of Okhamandal. The Samiani lighthouse-keeper brought in daily a more than ample supply for our kitchen and from this source I found the following fishes to be among the most frequent, namely :—

Lutjanus sp., *Serranus areolatus* (Forsk), *Serranus fasciatus* (Forsk), *Diagramma* sp.

Polynemus sp. and a species of *Sciæna* would also appear to be common in this district.

(*c*) Several times when off the coast in the steam-launch, shoals of silvery fishes were frequently seen covering considerable areas with their closely-packed ranks. Some appeared to be Clupeoids (herring family); others were undoubtedly of the mackerel group.

A fact of significant importance is the big export fish trade which I believe exists along the coast of Sind and the State of Kutch. Even in Ceylon a quantity of the dried fish sold appears to come from the latter district, a certain quality being known as Kutch fish.

Considering the variety and luxuriance of the marine fauna and flora of the seas around Okhamandal, it would be incredible indeed if a large fish trade be not capable of development, especially when we note that natural salt is produced very extensively

and cheaply in the district, and that the climate is exceptionally dry. Rain seldom falls, and while this results in frequent famine and ruin to the agriculturist, the fish-curer, who lays his prepared fish to dry in the open, has no fault to find with such arid conditions.

Beyt Harbour is an ideal haven for the location of the headquarters of a fishing fleet, exploiting on the one hand the long stretches of muddy and gravelly bottom of the Gulf of Kutch, and on the other the teeming surface waters of the Arabian Sea. Even now, without the distributing conveniences which a continuation of the railway from Nawanagar to Aramra will supply, a great deal may be done to lay the foundations of a most profitable industry. The arid land, pre-eminently dry climate, and super-abundant natural supply of salt to be had for little above the cost of cartage, makes the situation of Adatra, facing Beyt town, an ideal place for the salting and curing of fish on a scale of great magnitude.

The collection of pearl oysters and chanks, the culture of edible oysters and of window-pane oysters can never attain large proportions in this district under any possible conditions, owing to the restriction imposed by the limitations of area and coast-line, but the growth of the industries of sea-fishing and fish-curing have no such natural restrictions. Their expansion will be concurrent with the energy and capital of the men who engage in it, and need be limited by commercial considerations alone.

There are and will be difficulties attendant on any efforts made to start a fishing industry; one of these may be the fear of hurting the religious susceptibilities of those multitudes who regard Beyt as a holy city not to be entered by low caste men, not to be defiled by the spilling of blood or the sale of the flesh of animals. But as Adatra on the mainland is suggested as the location for the proposed industry any difficulty of this nature will be minimised.

Incidentally I hazard the suggestion that, if no religious or caste scruples bar the way, the Vaghers probably would make excellent fishermen—certainly the curing of fish ashore is well within their capacity. Seeing that they come of a race of freebooters, men ever ready for a broil or for piracy if it offered, they should have that courage which the calling of a fisherman demands. If they should ever take to such a life, then the present suggestion would go far to solve what appears to be a recurrent industrial problem in Okhamandal in regard to the finding of congenial or satisfactory employment for this clan, whose old occupation of preying on their neighbours being ended, seem to have difficulty in finding work that will satisfy what we must consider to be an instinctive longing for excitement.

An industry of the potential value possessed by sea-fishing has, however, a wider importance than the provision of a trade to a single clan; the successful carrying on of a large and profitable trade would do much to ameliorate the periods of distress and famine due to continued lack of rain which afflict Okhamandal so frequently. On the occasion of my visit no adequate rains had fallen for over two years; no crops

had been harvested during this period over the country as a whole, the peasantry and villagers were penniless, and but for the famine relief provided by the Government of H.H. the Gaekwar, many would have had to face death from starvation.

If a fish trade be established satisfactorily, and if religious scruples can be overcome, many of these same people under similar conditions may earn fair wages by participating in one way or another in a fish-curing industry, greatly to their own benefit as well as to that of their Government.

To turn the possibilities outlined above into actuality, to create and establish an industry characterised by comparative complexity due to the varied character of the methods that must necessarily be employed and which require to be directed by specialised skill and technical knowledge of a high order, is a problem calling for the most careful thought and preparation. Discredit and failure are bound to ensue if any attempt at rushing the project be made; the allied operations of catching, curing and distributing must gradually evolve through the necessarily slow processes of investigation and development. In Europe or America, where fishing and curing have attained a state of high development and organisation and where skill and capital are available whenever there are fair prospects of large profits to be made in the opening up of new fishing grounds or the inception of a newly-devised industry, such an undertaking as that now suggested above would certainly be taken in hand by private enterprise, by some firm already in the trade having the command of the experience, apparatus and capital needful. In India, for various causes, native enterprise is extremely conservative, greatly disinclined to strike out in new lines until such have been proved by others—by Government or European enterprise—to be capable of yielding good returns; in other words, initiative is lacking in large measure. In the present instance the requirements of the case are such as cannot be grappled with except by initial investigation and subsequent pioneering conducted by Government. As a commencement, full information must be collected on the methods of fishing and curing already employed successfully on the neighbouring coasts of Sind and Kutch; if possible, by one who is an expert in fishing and curing, in order that he may be able to assess the advantages and disadvantages of the methods hitherto employed, and to advise what modifications and innovations should be introduced. The next step will then be to ascertain what fishes of food value are available in such numbers in the sea around Okhamandal as to be worth fishing for specifically; in other words, a fish census will have to be taken by means of such nets, lines, and other means, as the officer in charge of the investigation may deem most suitable. The most effective methods of capture will next have to be ascertained by practical experiment, together with the forms of curing suitable for the markets to be catered for. A modest and temporary experimental station may be found desirable as the headquarters of the expert where he may carry out his experiments. Here, too, he would be able to make a series of demonstrations for the benefit of such of the local men of standing and

enterprise as may be persuaded to take an interest in the proceedings. The eventual success of the project will in large part depend upon the degree of interest aroused locally and of co-operation secured from the wealthy trading community, and every effort would have to be made to enlist their active sympathy.

I suggest the vicinity of Okha Point as the most suitable site if the establishment of an experimental fishing station be eventually resolved upon.

In conclusion, I trust the time is not distant when we may see cured fish forming the chief export of Okhamandal, providing cargoes for regular coasting steamers and a fleet of buggalows trading with the great fish-consuming centres of India, Ceylon and Africa ; I hope also to see the day when, rail connection being established between Beyt and the main railroad system, refrigerating vans may carry the soles and pomfret of Okhamandal to India's inland cities.

SUMMARY OF RECOMMENDATIONS.

The following synopsis of recommendations for the improvement and greater utilisation of the marine resources of Okhamandal may be divided conveniently into three sections, namely :—

(I) Those suggestions and operations which require no special or expert knowledge, and which may be put in hand forthwith by the local authorities, if approved.

(II) Those which necessitate the officer in charge of the operations having had some moderate degree of special training such as may be procurable, I trust, before long at the fishery experimental stations now being established by the Madras Government.

(III) The very important recommendations relating to the establishment of sea-fisheries and fish-curing operations which must be preceded by a special local investigation requiring the services of a first-class expert and organizer.

I shall accordingly take these sections separately, and recapitulate briefly the recommendations given in detail on the preceding pages.

Section I.—Recommendations requiring no Specially-trained Supervision.

A.—*The Pearl Oyster Fishery.*

(α) The reservation in rotation for stated periods (say of two years) of the different sections of the coast; during this time all fishing shall be forbidden in the section proclaimed.

(*b*) That the leasing of the right to collect pearl oysters be offered periodically *in conjunction* with the lease of the chank fishery ; that the lease be for a term of either three or five years.

B.—*Window-pane Oysters.*

(*a*) Teach the lads of the coast villages both swimming and diving.

(*b*) Watch for the occurrence of a large bed of mature oysters, and then endeavour to lease the fishery of the bed to a Karachi or local contractor.

(*c*) Stipulate in any lease made, and also by formal proclamation, that no window-pane oysters under four inches and a half in longest diameter may be brought ashore under penalty ; that any undersized shells which may be found in the course of fishing be put on one side and relaid on the bottom *convex side downwards*, in a specially demarcated area adjacent or convenient to the fishing ground.

(*d*) When once the industry be established, it will be preferable that the lease of the fishery be for terms of either three or five years, rather than for a single year, as the former arrangement gives the renter a deeper interest in the prosperity of the fishery, and also gives him a chance to recoup loss sustained in a bad initial season.

C.—*The Chank Fishery.*

(*a*) The chank and pearl oyster fisheries to be leased in conjunction whenever possible, and to be for periods of either three or five years.

(*b*) That the fishing grounds be divided into four or five sections, as may be convenient, and that these be closed to fishing in rotation for stated periods. Thus, if the grounds be divided into the five sections of (1) west coast, (2) Okha Point district, (3) Adatra shore, (4) islets and banks off Beyt Harbour, (5) Beyt Island, including Hanuman Dandi and Chindi and other reefs, each in turn would be forbidden to the lessee for a period of, say, two years. At the end of this time the section would be reopened to fishing, and the section next in rotation closed in its turn for a similar length of time.

(*c*) All chanks small enough to pass through a circular aperture of two and a quarter inches diameter, in a gauge made for the purpose, to be returned *alive*, under penalty, to the sea at the end of each day's fishing. To sell, or offer for sale, such undersized shells to be made an offence punishable by fine. Gauges to be kept by the local officials at the fishing and sale villages.

SECTION II.—RECOMMENDATIONS REQUIRING TRAINED SUPERVISION.

A.—*Chank Culture.* If this be resolved upon I recommend :—

(*a*) That a number of chank egg capsules be obtained, say by reward offered, and placed in a suitable pound or enclosure, where, after hatching, the young shall be safeguarded for some weeks till, being of a size better fitted to enable them to cope with enemies, they be distributed to the principal chank grounds.

(*b*) Later on, when further experience be gained, numbers of sexually mature adults may be impounded with a view to obtain egg capsules more readily, and in greater numbers.

B.—*Culture of Edible Oysters.*

When an officer with sufficient training be available, I suggest that he should be instructed :—

(*a*) To ascertain the limits of the spatting season, and to determine the factor which supplies the stimulus necessary to induce emission of the sexual products ; whether this be increase of temperature, as in Europe, or decreased density of the water consequent upon monsoon floods, as is the factor in Southern India.

(*b*) To set spat collectors of different forms in different places in Aramra Creek at the beginning of the spawning season, and to note the comparative results with exactitude.

(*c*) When the young oysters thus obtained be of sufficient size, to detach them and "lay" them on prepared bottom on the banks of the creek.

(*d*) To vary the experiments as greatly as possible with a view to ascertain what procedure gives the best results locally.

SECTION III.—SEA-FISHING AND FISH-CURING.

While restrictions of area preclude any great development in the case of all the preceding marine products, sea-fishing is wholly without such hampering bonds ; on the other hand, as no nucleus of such an industry exists on or around which to build and develop, a great amount of preliminary investigation and effort is requisite before practical work on a commercial scale can be attempted. The first requisite is to obtain a well-trained and level-headed expert *having practical knowledge* of the more important methods of fishing as practised in other countries. To him should be entrusted the task of ascertaining :—

(*a*) All that is worthy of note in the collecting, curing, and distributing of fish on the neighbouring coast of Sind.

(*b*) What marketable fish exist in fishable quantity in the sea within fishing range of Beyt Harbour.

(*c*) What will be the best methods of capturing these fish, bearing in view local circumstances and that it is specially desired that native talent and capital shall eventually develop the industry. He will have to experiment with various forms of nets, lines, and, if possible, with pounds and traps—the latter specially suitable in the shallow waters of Balapur and Rann Bays.

(*d*) He should also supervise experiments, employing modern methods, in the preservation of the fish caught, and should as far as possible demonstrate the processes to selected individuals, nominated by the local authorities, who, it is to be hoped, will eventually be able to take charge of the practical operations when the time comes for placing the matter on a commercial basis.

(*e*) A small experimental station should be erected at a convenient location near Okha Point. This, however, must necessarily await the appointment of the officer to be charged with the conduct of the investigations, and who will advise what boats, nets, and other gear will be requisite.

JAMES HORNELL.

COLOMBO, *June 25th*, 1908.

H.H. The Gaekwar's steam-launch "*Pari.*"

MARINE RESOURCES OF OKHAMANDAL.

LIST OF FULL-PAGE PLATES.

PLATE

I.—View of the great temple of Dwarka from the south.

II.—A memory of Samiani Island.

III., fig. 1.—The shore plateau north of Dwarka.

„ „ 2.—Rock-pools on the shore plateau north of Dwarka.

IV.—A colony of *Palythoa tuberculosus* in a Dwarka rock-pool.

V.—Erosion into knife-edged hollows of a bed of calcareous sandstone at high-tide level, Dwarka.

VI.—A forest of the tubes of *Eunice tubifex*, low spring tide, Kiu, Beyt Harbour.

VII.—Sea-fans and spiny Alcyonarians (*Dendronephthya*) exposed at low tide, Kiu.

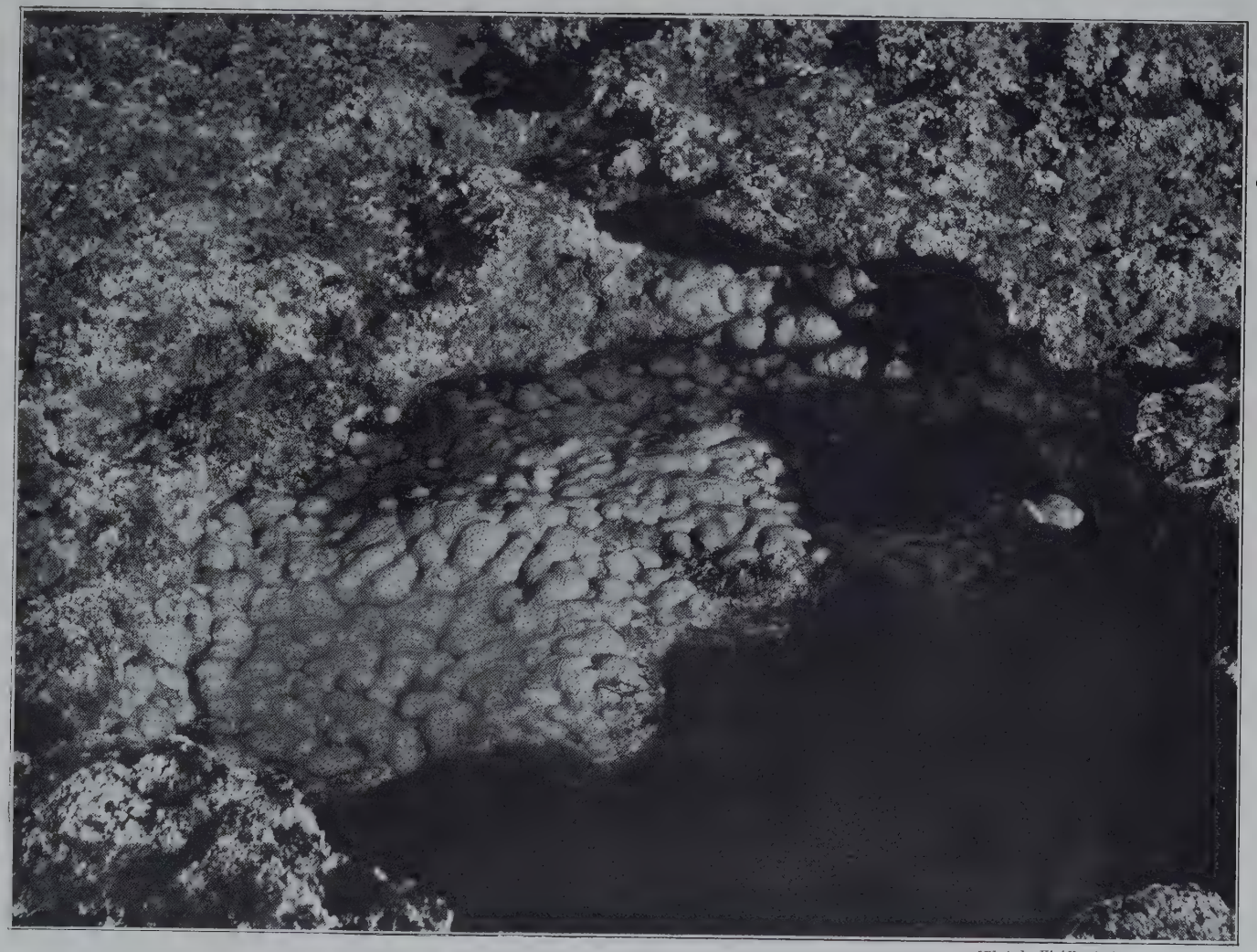
VIII., fig. 1.—*Discosoma*, a giant anemone, photographed in full expansion.

„ „ 2.—Hanuman Dandi reef, an example of a well-marked plane of marine denudation.

Fig. 1.—The Shore Plateau north of Dwarka headland.
(The view is taken looking southwards.)

[*Photos by Vividha Kala Mandir, Baroda.*

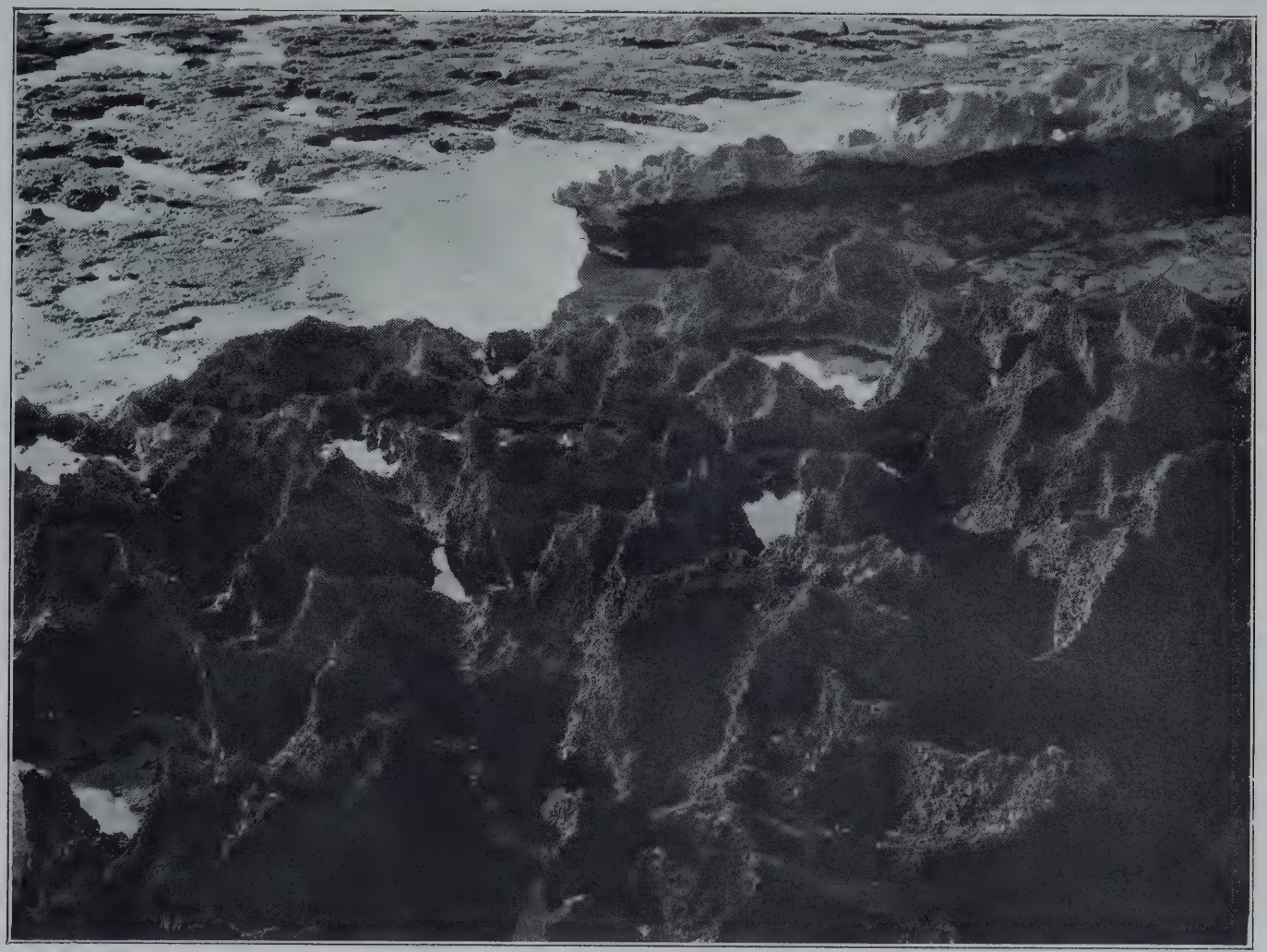
Fig. 2.—Low-tide pools on the Shore Plateau north of Dwarka headland.
(View looking northwards.)



[*Photo by Vividha Kala Mandir, Baroda.*

A huge colony of the actinian *Palythoa tuberculosus* mantling the bottom and sides of a low-tide pool on the Dwarka littoral. $\times \frac{1}{8}$.

(See Plate III, Fig. 2.)



[Photo by Vividha Kala Mandir, Baroda.

Erosion into knife-edged hollows of a bed of calcareous sandstone at high-tide level north of Dwarka headland.

(Photo by Vivekha Kala Mandir, Baroda.

A forest of the tubes of *Eunice tubifex* draped with zoophytes and polyzoa at extreme low tide, Kiu littoral, Beyt Harbour.

[*Photo by Vividha Kala Mandir, Baroda.*

An extremely low tide at Kiu, Beyt Harbour.

Sea-fans (Gorgonids), and spiny Alcyonarians (*Dendronephthya*) appearing above the water. In the centre is a massive sponge perched on a rock, beyond it and a little to the right the pale crown of a yellow *Dendronephthya brevirama* shows clearly. To the right of this the twigs of a large sea-fan (*Lophogorgia lutkeni*) are seen.

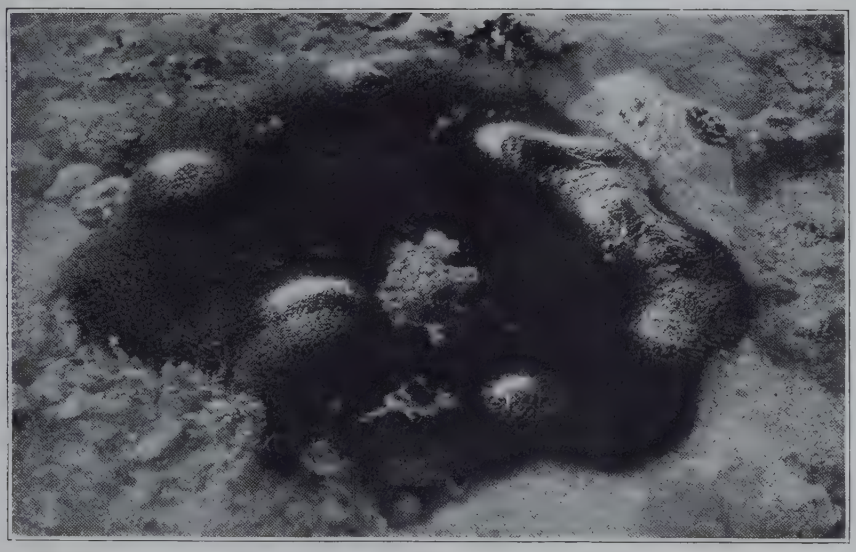


Fig. 1.—Discosoma, a giant Anemone.

Photographed in a state of full expansion in a pool on the Hanuman dandi reef. The mouth is in the act of discharging a mass of excreta. One-sixth of actual size.

[*Photos by Vividha Kala Mandir, Baroda.*

Fig. 2.—Hanuman Dandi reef exposed at low tide.

Note the well-marked plane of marine denudation and the outcrop of calcareous strata in the foreground.

NOTE ON
THE INDUSTRIAL DEVELOPMENT OF OKHAMANDAL,

BY

DEWAN BAHADUR V. M. SAMARTH, B.A.,
Sar Subha of Baroda State.[1]

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1. The administration of Okhamandal Taluka is beset with many exceptional difficulties; the district is situated far distant from the central Government at Baroda; it is not easily accessible at certain seasons; a portion of its population is of a turbulent character and is responsible for the introduction of dual control in matters administrative; finally, the seasons are uncertain and the soil is not fertile. Financially, the Taluka is a heavy drain on the general revenues of the State.

2. But there is another and more cheerful way of looking at this distant possession of His Highness the Maharaja Gaekwar. It is a place sacred in the eyes of all devout Hindoos and the thousands of pilgrims who visit it from all parts of India are able to attest the power and glory and beneficence of the Hindoo *Dharma Raj*. And there is yet another way of looking at it; the very difficulties of the administration are most certainly its opportunities. Here is afforded to the student of Indian politics an object lesson of British and Indian officials co-operating more closely and on more equal terms than elsewhere, in the daily duties of governing

[1] This note was written by Mr. Samarth several years prior to my deputation to Okhamandal to enquire into the marine resources of that district. It typifies that spirit of progress which pervades the administration of Baroda under the wise and energetic rule of His Highness the present Maharaja Gaekwar. I am specially pleased to insert it in this report as it throws an interesting light upon the present condition and prospects of the people of a district once notorious for lawlessness and piracy, and which has been a source of trouble alike to the Governments of India and Baroda for many generations.—J. H.

a backward population and leading it, much against its will, upon the path of progress in civilisation.

3. The details of the history of the Taluka during the past century are sufficiently well-known. From piracy to settled civilised Government is a change any community may be thankful for. One is not certain that this is the feeling of the Waghers on whom peace has been imposed by the strong hand; but that it ought to be and will be their sentiment, to my mind, is beyond doubt. But for the unreliable disposition of the Waghers towards the new order of things, the administration of the Taluka even from distant Baroda would not be difficult. Out of a population of about 21,000 souls, about 4,000 are Waghers, a little over 1,200 of whom are adult males. This apparently insignificant proportion of the population is at the root of most of the evil and mainly, if not solely, to keep them in order entails an annual expenditure of over a lac of rupees necessitated by the maintenance of a battalion of disciplined sepoys and the establishment of a British Assistant Resident. The last Wagher outbreak took place 40 years ago. Since then these tribesmen are gradually settling down, *nolens volens*, to quiet ways and are taking to agricultural life. At the present day they have all turned cultivators but they have not yet acquired the skill and the virtues of thrift and industry which are so essential to make successful agriculturists. The dignity of labour has not yet become ingrained, and other forms of manual labour than agricultural they affect to despise. They should not be blamed; rather do they stand in need of sympathy and pity for their present failings. Considering their past, one ought to be satisfied with their present achievements. They are less troublesome now than they were and will be less and less so, as the rate of their progress in civilisation becomes accelerated. What is needed now is to make them acquainted with skilled modes of agriculture and to teach them some handicrafts. That is to say, they must be given opportunities to improve their status in the world materially and mentally.

4. The other classes of the population of the Taluka are also more or less backward in intelligence and enterprise, but the Waghers are very far behind even them. With the Waghers I include the cognate tribes of Wadhel Rajputs. Of the other classes, the Bhattyas are the most forward; they are good traders. Next to them are the Memons, who as cultivators, as oil pressers, or as petty traders, though poor, are well able to take care of themselves, except in regard to elementary education. The Lavans too are thriving. It is the Waghers who need direction and encouragement more than the others.

5. Okha is not totally devoid of mineral resources; gypsum, manganese, and building stone are all available. But in what quantities these exist and whether it is possible to establish industries in these products having a fair probability of

commercial success remain yet to be investigated. There is also salt which nature produces in abundance and which can be had for the gathering. But political circumstances are such that this source of wealth is allowed to go to waste. The attitude of the British Government in this respect is not in my opinion helpful, but this by the way. Finally there is the possibilty of developing a pearl fishery, a question, however, which must be taken in hand by an expert.

6. Okha should be connected with the Kattiawar system of Railways, and the port of Beyt should be improved. The advantages of so doing would be very great. In the first place the disadvantages which exist at present owing to distance from Amreli and Baroda would vanish. Under prevailing conditions two battalions of sepoys have to be maintained, one at Dhari and the other at Dwarka; one of these could be safely dispensed with and the expenditure involved in its upkeep saved. It would be very easy to move troops to or from Dwarka and Baroda or Rajkot were the Railway extended to Dwarka. Even if there were no other income assured from the construction of a railway, the consideration that a saving of expenditure on either the Okha or the Dhari Battalion would be effected, should in itself be a strong incentive to the undertaking. But as a matter of course, considerable revenue would accrue from pilgrim traffic which would increase immensely and from trade which the port of Beyt would attract when connected with the general Indian railway system. An important reason, besides the excellence of these ports as safe anchorages, why trade would favour Beyt and Dwarka is that being treated on a level with British Indian ports for purposes of customs tariff, a status not granted to the neighbouring ports of Kattiawar, exports from Okha ports would be, and actually are at the present day, exempted from customs dues at British Indian ports; as for imports, we are free to tax them or not at our pleasure, if they come from British Indian ports. These are important advantages and would help a railway to earn good income should we construct it.

7. Of minor sources of wealth, Okha produces ghee, wool, sesame, and castor. It is possible to develop tobacco cultivation and even cotton and although no afforestation appears practicable owing to the violent winds which blow over it saturated with saline matter destructive of vegetable growth, my idea is that the non-arable waste land which exists in abundance may be planted with googul which grows naturally if protected from goats, sheep, and camels and is capable of yielding some revenue from its gum and from its wood which is used as fuel when dried.

8. The great sources of revenue, next after the land tax (Rs. 32,850) which is only nominal in it incidence, are the pilgrim tax (Rs. 35,900) and the customs duties (Rs. 26,125). The total revenue of the Taluka from all sources is Rs. 109,250 and the total expenditure is Rs. 203,700, a normal deficit of Rs. 94,450 annually.

But one need not lose heart owing to such a state of things. Here is an opportunity to strive and rise superior to difficulties.

9. I have indicated ways and means above whereby the Taluka administration may be made self-supporting, namely :—

I. The construction of a railway and the improvement of the port of Beyt, and

II. The improvement of the status of the ryots by raising them in character, intelligence and capacity.

Let us lay the foundation of a policy calculated to bring about these ends, and await the result patiently; with the co-operation of the British authorities I am certain we should succeed.

10. With regard to the education of the people my ideas formulated in the following paragraphs have been more or less formed or confirmed by what I have had the opportunity of recently seeing attempted in Ireland and in England. The problem before the Irish Government in regard to certain parts of that country is in many respects not dissimilar to the problem which confronts us in Okha. In England the work attempted at the Red Hill Reformatory, which came particularly under my observation, impressed me as being of the utmost practical value for us as administrators of backward populations some of which are actually classed as criminal.

11. Compulsory Primary Education.—Through the head to the heart; this appears to me to be the most natural and suitable method of educating the young. No satisfactory results can be achieved without first making the children go through a regular course of primary education and in the present stage of society in Okha and especially so far as the Wagher population is concerned, primary education must be made compulsory, but its introduction must be gradual. To commence with, it must be free, no fees being charged. At every convenient village, there should be a well-equipped school and all children, boys and girls of all classes, whether Wagher or non-Wagher, within a radius of three miles, should be under compulsion to attend school regularly between the ages of seven and twelve except at busy times of agricultural work, such times to be fixed with due regard to local conditions and the habits of the people. No more than ten such schools would be required besides those already existing at Dwarka, Varwala, and Beyt. Schools were established at Aramda, Dhinki and Dhrasanwel which owing to scanty attendance have been closed and, although famine has left the Taluka, have not been re-opened. These schools should be re-opened and the buildings enlarged so as to afford accommodation for a much greater number of children than they were intended for; the remaining seven schools should be opened at convenient centres, with accommodation for the number of children belonging to the neighbouring villages. Supposing Rs. 500 (five hundred) to be the cost of the buildings and outhouses of each school, the ten schools would cost Rs. 5,000,

out of which about Rs. 200 for each of the existing two schools at Goriali and Wasai, making a total of Rs. 400, may be deducted, leaving only Rs. 4,600 to be provided as initial cost of buildings. About Rs. 50 worth of furniture would be required for each school, which for ten schools would be Rs. 500 more. Rs. 5,100 would, therefore, be about the initial outlay involved on the primary schools supposing there be no payments required for the salaries of schoolmasters. To effect this latter object I propose to submit proposals for the amalgamation of the Revenue Mehtas with the educational village school staff. In this way the village Mehtas (Talatis) in Okha may be utilised as teachers. There will be in that case no expense except on school buildings which will also serve as choras. I think this scheme, if properly carried out, ought to answer satisfactorily and with one person appointed to each school, the monthly expenditure on salaries and contingent expenses need not exceed Rs. 20 per school or Rs. 200 for ten schools, or Rs. 2,400 per annum. Books and slates the parents of the children may be expected to pay for in consideration of Government providing the school buildings and the teaching staff. According to the census of 1901, taking only Wagher children, there were :—

Age.	*Boys.*	*Girls.*	*Total.*
5–12 years	640	831	1471
12–15 „	255	185	440

There would be about an equal number of children belonging to other classes in the villages. If we omit girls for the present owing to prejudice on the part of the parents, the number of pupils (boys only) to be taught in schools will be very manageable.

12. Of boys between the ages of 12–15 I would take only 10 per cent., which for all classes need not exceed 75, and for Waghers alone only 25. I would take only the Wagher boys, leaving the other classes to voluntary effort after 12. These 25 Wagher boys should be taken to Dwarka and a boarding establishment formed for them at State expense.[1] Here they should be taught higher vernacular standards and practical instruction afforded in agriculture, weaving, carpentry and smith's work. A farm of about ten bighas and a workshop should suffice for all their education. My idea is that the annual expense under all heads on this institution should not exceed Rs. 2,500 exclusive of the initial expense of a suitable house and furniture. A house may be hired or built.

13. These twenty-five boys should eventually be started in their respective trades, for which purpose a small advance in money or material may be made to them

[1] We may postpone this, however, for three or four years to await the results of the village primary schools.

not exceeding, say, Rs. 50 each. But this item may be determined when the time arrives, judging separately the needs of each individual case.

14. The teachers for agriculture and the technical crafts need not be highly paid. Practical men from each trade may be selected as foremen on a small salary. This is what is done in schools in England and Ireland.

15. The boarding Institution need not be continued as a free institution beyond a period of ten years. It is expected that at the end of that period the people will have learnt to appreciate the value of practical education and will be willing to share the cost of it with the State, to the extent of half at least. Similarly after ten years the cost of village primary schools will be shared with the people, half and half, for another period of ten years.

16. It would also be expedient to encourage higher education among the Waghers by offering one or two scholarships of suitable value to deserving boys.

17. So far my scheme for the education of the Wagher youths would appear to be complete. It requires to be supplemented for a few years in the case of adult men who cannot be sent to school. Ten Waghers not older than thirty years may be selected for a special course of training every six months during a period of three years. In this way there will be about sixty Waghers in all during the course of three years who will be placed under training. For the present only one branch of industry may be taught them, say, by preference, weaving cloth from cotton or woollen yarn. There is demand for the rough cloth called Khadi such as is used in the country, also for sail cloth; the making of Dhurries may also be taught. Six months should be quite enough in which to teach the men these varieties of weaving. After they have become proficient at their trade they may be dismissed and then to enable them to start in business, implements of weaving may be advanced to them as Tagavi, the value of which may be recouped to Government by small instalments to commence from the beginning of the second year. Should they find difficulty in obtaining a ready market for their productions among local traders, for two years Government might give them work by advancing materials to last for a month at a time and receiving in return the finished articles to be paid for at a reasonable price fixed according to the state of the market at the time. Such articles Government would then sell direct or through middlemen as may be found the more profitable or desirable. Government must be prepared to incur if need be a small loss on this business regarding it merely as an educational measure adopted for the purpose of familiarising the Waghers with handicrafts and home industry.

18. For the purpose of instruction and supervision I should utilise the services of the jailor at Dwarka. He may be granted an allowance for doing this extra work and an advance of Rs. 1,000; but the expenditure on this experiment should not exceed Rs. 5,000.

19. An agricultural expert, a practical Kheddot, may be employed upon the agricultural scheme; his salary and travelling allowance need not exceed Rs. 25 per month and he may be allowed about Rs. 200 per annum for expenditure in connection with the purchase of seed, manure, etc. His business would be to teach cultivators, whether Waghers or non-Waghers, better methods of cultivation, manuring, selection of seeds, etc. His appointment would be for five years. On the expiration of that period the question of his retention may be reconsidered in the light of the experience gained from the results of his work in regard to improvement in general agricultural knowledge and skill among the people.

20. I feel certain the above measures, if adopted, will result in a great advance in the general well-being of the people and will entitle Government to their gratitude to a much greater degree than even the humane and generous policy followed in regard to famine distress has already evoked. The railway will be a great civiliser; the improvement of Beyt port will bring business, and education will fit people to appreciate and follow a life of industry. They will become more law-abiding than they are; much of the expenditure on the military force maintained at present it will then be practicable to curtail. The Wagher population which is at present forced to stay at home will be fit to emigrate as skilled wage-earners outside the limits of Okha to Karachi or Bombay or to distant Africa in the wake of the Bhattyas and Memons.

21. In conclusion I wish to state that I think Okha requires a highly centralised administration. Backward people fail to understand the real significance of a division of Administrative powers. Our chief official's position should be one of equal value, so to say, with that of the Assistant Resident. I have proposed in a separate vernacular memorandum the formation of such an administration.

I have also submitted memoranda for (1) the improvement of the pilgrim tax; (2) of the customs tariff; (3) of the fees for quarrying stones; and (4) I am in correspondence with the Settlement Commissioner on the subject of the existing mismanagement of the temple of Dwarka on the satisfactory conduct of which so much of our fame and revenue depends and which to the minds of all devout pilgrims is a grave scandal at present.

V. M. Samarth.
Subha, Amreli Division.

[Note.—Most of the recommendations contained in the above note after consideration by the higher authorities have been adopted, with varying results, since its submission in the official year 1902–03 A.D.—V. M. S.]

REPORT

UPON THE

ANATOMY OF PLACUNA PLACENTA,

WITH

NOTES UPON ITS DISTRIBUTION AND ECONOMIC USES,

BY

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[With Five Plates and Two Text Figures.]

The anatomy of the window-pane oyster (*Placuna placenta*, L.) has never been worked out, and references to it in the literature of the Lamellibranchs are scarce. The literature of the genus *Anomia*, to which *Placuna* is most nearly related, is likewise scanty. The principal is by F. J. H. Lacaze Duthiers, who published in 1854 a "Mémoire sur l'organisation de l'Anomie." [1]

A short critique of this by Pelseneer appeared in 1891,[2] in which he amplified and corrected certain points, while Sassi [3] has contributed an important paper dealing principally with the renal system. Von Ihering [4] and Morse [5] have also treated of *Anomia*, and occasional references to this genus are to be found scattered through works dealing with the morphology of molluscs, but *Placuna*, though well known by reason of the minor economic uses which it subserves, has hitherto failed to attract that attention from the morphological standpoint which it undoubtedly deserves; the peculiar asymmetry exhibited by many of its organs possesses extreme interest when considered in conjunction with habits and habitat, while the strange mingling of primitive or archaic characters with others of extreme modification and specialisation has much that will repay careful study.

[1] *Ann. des sci. nat., Zoologie*, ser. 4, tome ii. 1854.
[2] "Contribution à l'étude des Lamellibranches" (*Archiv. de Biologie*, tome xi. 1891).
[3] "Zur Anatomie von Anomia ephippium" (*Arb. Zool. Inst. Wien*, xv. Heft 1, 1903).
[4] "Ueber Anomia," etc. (*Zeitch. für Wiss. Zool.*, tome xxx., vol. supplem., 1878).
[5] "On the Relations of Anomia" (*Proc. Boston Soc. Nat. Hist.*, vol. xiv. 1871).

The general characters of the family Anomiidæ, which comprises *Anomia* and *Placuna* as its two distinctive genera, may be summarised as follows :—

The organs exhibit a very high degree of asymmetry and the shell is distinctly inequivalve. The valves show a pronounced tendency to assume an orbicular outline, and are very much flattened or compressed laterally : the right valve is almost flat, the left weakly convex.

In young specimens the shell is thin and more or less translucent ; the periostracum is very delicate, and disappears soon after formation. Pigmentation of the adult shell is rare, though it is common among young forms to show a beautiful satiny pink or yellowish lustre.

The mantle edges are free and siphons are absent. A single adductor muscle (the posterior) is present, large, and situated sub-centrally. The foot is fairly well developed, either tongue-shaped or cylindrical. In *Anomia* the byssus is modified into a large and important calcified organ serving for fixation ; in *Placuna* a byssus is absent, even in the very young.

The visceral mass is asymmetric, the right aspect of most of the organs being developed at the expense of the left. The crystalline style is lodged almost entirely in the right mantle, and practically the whole of the reproductive glands are likewise in intimate association therewith.

The intestine is short, and lies posterior to the stomach. The crystalline style is of enormous relative length. Special sense organs, other than tactile, are little specialised. The heart lies dorsal to the rectum and projects freely into the pallial cavity : no pericardium is present, and the cœlomic cavity is reduced to insignificant or vestigial dimensions. There is a single aorta—the anterior.

The genital glands open into the kidneys. The sexes are separate as in the true pearl oysters (*Margaritifera* spp.).

The two ctenidia are smooth, with simple reflected tubular filaments, and are organically fused together along the median line ; each has a supplementary (or fifth) external lamella which is free and unattached to the mantle. The filaments are parallel and practically free, there being neither interlamellar nor interfilamentary organic unions ; cohesion is effected by means of interlocking cilia situated on the opposing lateral faces of successive filaments : in *Placuna* certain of these ciliated areas are developed into true "ciliated discs" ; in *Anomia* the opposing cilia interlock, but are not specialised into "discs."

The genera of the family Anomiidæ, as already pointed out by Pelseneer, by the *ensemble* of their organisation, are among the most archaic of existing Lamellibranchs —notably in the simple structure of the branchiæ, in the position of the heart dorsal to the rectum, in the muscular structure of the auricles and in the absence of a posterior aorta.

With these persistent archaic characters are associated several curious and highly-

developed specialisations, the chief being, in *Anomia*, the calcified byssus, and in *Placuna* the single genital aperture, and the development of the foot into a very long and trumpet-shaped organ.

In both genera the unequal development of the two nephridia and the obliteration of the pericardium are most noteworthy; in *Anomia* Pelseneer held (*loc. cit.*) that the pericardial cœlomic cavity is reduced to an insignificant connecting channel between the kidneys, but Sassi contends (*loc. cit.*) that the cœlomic cavity is represented by certain groups of saccate glands opening into each nephridium; in *Placuna*, as I believe and suggest, it is to be correlated with a glandular body on each side, which opens into the anterior horn of the kidney of its side—a view which strengthens Sassi's contention regarding the organs he describes in *Anomia*.

Before entering upon a detailed description of the organisation of *Placuna placenta*, it may be useful to give here a brief *résumé* of the distribution of the species treated of, with notes upon the economic uses to which it is put.

DISTRIBUTION AND HABITAT.

Placuna placenta, Linn. has a range extending from the Arabian Sea on the west through the Indian Ocean and Malayan Seas to the coast of China on the east.

The special habitat favoured by this mollusc is the muddy bottom of coastal bays; in many cases these bays are more or less completely landlocked, with a characteristic association of mangrove swamps along the shores; frequently the water of such bays is slightly brackish by reason of the rivers and streams that debouch thereinto. *Placuna placenta* appears, indeed, to be able to withstand a considerable admixture of fresh water, as we find it in such muddy estuaries as Karachi Harbour and other bays and creeks on the outer edge of the delta of the Indus; even in tidal rivers and backwaters cut off from the sea by surf-beat sandbars *Placuna* thrives, as, for example, in the Sambore River and the adjacent backwaters near Trincomalee in Ceylon. In Tampalakam Bay, also in Ceylon, I have found the specific gravity of the water over the *Placuna* beds to range during the dry season as low as 1·019 to 1·015 at temperatures 87° to 90° F., the open sea being 1·023; in the rainy season it must be notably lower.

On the other hand, the past fishery experiences of the Tampalakam beds have shown that an unusually large influx of fresh water during an exceptionally wet season entails the destruction of the oysters. The same adverse influence of an excessive admixture of fresh water has been noted at the window-pane oyster fishery near Tetabuan, on the east coast of British North Borneo, where the flow of the adjacent rivers in flood not infrequently causes widespread mortality.

With all this adaptation to life in distinctly brackish shallow water areas, I have found that *Placuna placenta* is capable of attaining large individual size, and of living

in robust health in the open sea and at a depth of several fathoms. Thus, I have seen quantities thrown up on the open beach at Nilaveli, some seven miles north of Trincomalee, and, again, during a cruise of the steam trawler *Violet*, during the past summer (1907) along the Coromandel coast, numerous specimens were trawled in the open sea from a muddy bottom in seven fathoms, at a distance from seven to nine miles eastward of Negapatam; I have also several dead valves trawled from the Periya Par, one of the Mannar pearl-oyster banks, situated twelve miles off the west coast of Ceylon. More recently I have found living individuals cast up during stormy weather along the coast adjacent to Madras.

The shells of those individuals that live in shallow bays and creeks are perfectly transparent for the greater part of the first year of life; the general anatomy of the animal can be seen, even to the beating of the heart. At this stage the valves are clear as the finest mica flakes, which they resemble closely, even to the readiness with which they may be split into further laminæ. As they become older the valves assume a more massive appearance, and generally turn white and translucent in place of being clear and transparent.

The very young, up to the time they reach a diameter of two inches, not infrequently exhibit ray bands of pale transparent pink diverging from the hinge, and broadening as they approach the free edge of the shell. A few are almost entirely suffused with this pale pink tinge, but the great majority exhibit no colour even in the youngest stages, and all shallow-water shells become colourless and sub-translucent after one year and a half.

A marked distinction between the shallow-water (brackish water) forms and those I have seen from the open sea is that in the latter a well-marked reddish-brown radial banding of the shell appears to be normal. It was characteristic of the great majority of the trawled individuals, and was persistent in the largest specimens examined (twelve centimetres diameter), whereas, as already stated, red colouring is transient, and comparatively uncommon in those found in muddy bays. The tinge among the latter is also much fainter, lacking the intensity and depth that is a noteworthy characteristic of those from several fathoms in the open sea.

The bottom favoured by *Placuna placenta* is a fairly stiff or pasty greyish-black mud. On this the shells generally lie prone upon their convex left valves, the hinge region sometimes slightly sunk in the mud, which may lightly cover the dorsal third of the shell. Native divers also aver that occasionally they are sunk more deeply, and that they may even be found, though this is rare, planted vertically after the manner of *Pinna*; if so, this is an abnormal position, and one which, I believe, must quickly entail death.

Few conspicuous animals are associated with *Placuna placenta*. Both flora and fauna are scarce; few organisms have adapted themselves to life in such environment. In Tampalakam Bay the only other animal of importance and abundance is the peculiar

suberitid sponge known as *Kadalpalam* (sea-fruit) to the Tamil divers. In the Gulf of Kutch a similar or closely related suberitid is associated with *Placuna*, and in the same locality we also find *Lingula* and a large yellow *Dendronephthya* living on the same ground. Algæ are scarce, and those seen are all green and mostly fleshy genera such as *Codium*. The valves of *Placuna* seldom bear any crusting or parasitic growths such as are so familiar on the shells of the true pearl oyster (*Margaritifera vulgaris*). When such are present they consist chiefly of sheets of encrusting Bryozoa.

I have never seen the valves attacked by the burrowing sponge *Clione*, but the tubular burrows of the polychæt *Polydora* are sometimes not uncommon. The sandy tubes of another polychæt, *Eunice indica*, are also at times fairly abundant attached to the valves.

Placuna does not appear to have many enemies; fishes are the principal, and their damage is largely confined to biting pieces out of the margin. Shells so mutilated are not infrequent; photographs of two shells so damaged are shown in Plate I, fig. 2. Larval parasitic worms, both cestodes and trematodes (figs. 20 and 21), are frequently seen encysted on the mantle edge, and as fragments of this are ingested every time a fish bites a piece out of the margin of a *Placuna* shell, it is clear how the parasitic infection is passed on to a fish host in which the parasites will become sexually mature.

A remarkable feature in this connection is the early age at which the infection of *Placuna* may take place. I have sections through individuals of which the shell and the visceral mass are but 1·5 cm. and 4 mm. in diameter respectively, showing well developed larval cestodes (*? Tetrarhynchus*) encysted in the liver.

DETAILS OF DISTRIBUTION.

The following list comprises all the localities of which I have knowledge. It will be seen that it gives a chain of habitat practically unbroken from the mouths of the Indus to the south coast of China:—

India.—Karachi Harbour and numerous inlets and creeks along the Sind coast; Gulf of Kutch (Balapur Harbour in Beyt Island! and Rann Bay!); Bombay Harbour and vicinity; Malabar Coast; muddy creeks south of Tuticorin! Buckingham Canal and Pulicat Lake (Madras Presidency)! open sea off Negapatam in seven fathoms! thrown up on sea beach, Ennore, near Madras! Mergui Archipelago.

Ceylon.—Tampalakam Lake! Sambore River and adjacent backwaters (Willey); open sea off Nilaveli! (these three localities near Trincomalee); off Delft Island, Palk Bay, six to seven fathoms! dead valves in nine fathoms, Periya Par, Mannar Pearl Banks!

Malay Archipelago.—Various places in the Dutch Indies; North Borneo, notably at Labuk Bay; the Philippines; also in Cochin China and Southern China.

Diving for Window-pane Oysters in Rann Bay, Okhamandal.

ECONOMIC USES.

The name window-pane oyster, which travellers in Southern China have given to *Placuna placenta*, indicates the use to which this shell has been, and is even yet, put in some Eastern countries.

During the days of Portuguese rule in India, when window-glass was a scarce and costly commodity, these shells were extensively used in the Portuguese settlements as a substitute. Fryer recorded this in 1675; the custom lingers in Goa to this day. Max Weber, writing in 1906, states that this window-glazing is still to be seen at Menado in the Dutch Indies and also in the Philippines. In Canton and other districts of Southern China, its use for the same purpose also continues; lastly, quite recently (1907) I saw a verandah at the Chinese Club at Cholon (Cochin China) roofed with these shells, while in the adjacent stream which intersects this town Annamite women were busy soaking and cleaning such large quantities of the valves as indicated considerable demand.

The shells chosen for the purpose of glazing are half-grown individuals: I should judge them to be eighteen months old. After soaking some time to effect the decay of the flesh, the shells are cleaned by being tossed and shaken together in baskets till all dirt and roughness are removed and a translucent mica-like appearance is obtained.

The former fishery near Bombay was to furnish shells for the purpose of window-glazing; so also is the collection that goes on in the Dutch Indies, Borneo, and the Philippines.

It would be interesting to discover the origin of this utilisation of *Placuna* shells; it is scarcely likely to have originated independently at such widely-separated localities as China and Western India. I am inclined to credit its origin to the Chinese, and its dissemination to the Portuguese, who in the height of their power linked up East and West as Britain does to-day. At their great trading centre of Macao, close to Canton, they would early become familiar with the Chinese use of *Placuna* shells, and their officials would thence carry this knowledge to the scores of stations dotted along the coast-line of the Indies.

In certain localities *Placuna placenta* produces quantities of minute pearls, but as these suffer from the four vital defects of small size, poor lustre, irregular shape and lack of the great hardness characteristic of gem pearls, their value is low, and the uses to which they are put are such as will lose importance when fanciful medical nostrums and old superstitions give way before the advance of iconoclastic Western ideas.

To meet this curious demand there are at least four localities where beds of *Placuna placenta* are fished more or less intermittently and irregularly for the sake of these seed pearls. They are those of Sind (Western India), Tampalakam Bay in Ceylon, Labuk Bay in North Borneo, and the Dutch Indies.

The fishery in Sind is of comparatively recent origin. It was discovered by the Mirs about 1836. Since the British Government took possession of Sind, the fishing of the banks has been leased by Government periodically for very variable amounts, ranging from the comparatively high figure of Rs. 6,205 in 1849 to as low as Rs. 617 per annum for a period of three years in 1904, a gradual diminution of revenue due without doubt to over-fishing and the financial impossibility of maintaining a supervising establishment adequate to enforce a proper regard for cultural safeguards.

The industry in Ceylon has run a parallel course; it has a similar tale of gradually diminishing prosperity, due to over-fishing and poaching. As on the Sind coast, the Ceylon *Placuna* fishery is the property of Government, and the leasing-out system is also the one adopted. Under the circumstances which prevail at Tampalakam, and the comparative pettiness of the industry, this would seem to be the only practical method. What is wanted is efficient supervision, but here, as in Sind, it is difficult to reconcile theoretical requirements with financial soundness.

A detailed account of the Ceylon industry, and of the physical and biological conditions of the *Placuna placenta* beds, will be found in Part II, pp. 41 to 54, of the Ceylon Marine Biological Reports (1905).[1]

Since then an ordinance has been enacted formally vesting the monopoly of the

[1] Also as Ceylon Government Sessional Paper, No. xlvi., 1905.

fishery for window-pane oysters in the Ceylon Government, and giving powers to the authorities to make regulations for a close season, a minimum size limit, and other protective and cultural measures which may be considered desirable from time to time.

The lease of the beds at Tampalakam was next advertised, and was taken up in December, 1906, by a native syndicate at an aggregete rental of Rs. 17,700 for a term of five years from January, 1907. Among the stipulations were (*a*) a minimum size of five and a half inches in shortest diameter of the shells, and (*b*) a close season extending from May 15th to the end of December in each year. The results of the first year's fishery proved a dismal failure, largely owing to previous extensive poaching. The total of oysters fished is stated by the lessees at 627,672, the number being known with exactitude, as a payment of 25 cents (=fourpence) per thousand is made for opening them. From this quantity the lessees declare they obtained but forty-six rupees weight (say 46 tolas) of pearls, worth about Rs. 690, or one rupee ten cents (say one shilling and sixpence) per 1,000 oysters ![1]

The seed-pearl fishery in North Bornean waters is less well-known than either of the preceding. It also is owned by the Government, but in spite of being situated in a wild region, where civilisation has but recently appeared in the persons of a handful of European officials, it appears to be under more efficient regulation, and to promise a more continued prosperity than in the case of Ceylon and Sind.

The principal banks of window-pane oysters occur there in Labuk Bay, and are largely fished from Tetabuan, a village inhabited by Bajaus, a Malay tribe that till recent years lived largely on the spoils of piracy eked out with desultory fishing. To-day the Pax Britannica compels a steadier life, and accordingly the Bajau has turned fisherman in earnest. He is skilful at his calling, and being a fairly good diver as well, he is able to take toll from the beds of *Placuna placenta* that exist literally at his door—his dwelling is on piles on the margin of mangrove swamps.

The Tetabuan fishery is carefully regulated with the co-operation of the village chief. No shell is allowed to be fished under four inches in diameter, and no one is allowed to search for shells without a licence.

From time to time, as the oysters mature, certain of the banks are opened to fishing. At such times the boundaries of the bed are marked out by flags, and the village chief superintends operations, seeing that neither immature oysters be fished, nor unlicensed divers be present. As in Ceylon, the water over the Tetabuan beds is quite shallow—eight to nine feet. Diving requires no apparatus save a rattan basket wherein to place the shells.

On return from the banks the women and children take charge of the oysters. First of all the shells are opened and the contents thrown into a large iron pan of water. When filled the pan is put on the fire and slowly heated, but not to boiling

[1] Dr. A. Willey, "Report on the Window-pane Oysters (*Placuna placenta*) in the backwaters of the Eastern Province," *Spolia Zeylanica*, vol. v., pt. xviii., Colombo, 1907.

point. The contents are then placed in a tub and allowed to remain for three days till thoroughly putrified.

When thus prepared the rotten mass is taken up, a small quantity at a time, and rubbed well between the palms of the hands, and allowed to drop into a dish of clean water, where the small pearls fall to the bottom. From time to time the dirty water is decanted and replaced by clean. So the process proceeds till all the flesh has been treated, when, after final rinsing, the seed pearls, called *selisip* by the Bajaus, are strained off, cleaned and dried, and made ready for the market.

They are sold by weight; the prices paid generally give the Bajau divers a fair return for their labour.

The Borneo seed pearls are bought up by Chinese dealers and exported to China, where the bulk is used in the preparation of various quaint medicines. The Chinese specially esteem pearl medicaments in diseases of the eye, and I have been told by a Chinese doctor that ground-up pearls are considered a specific for syphilis.

Some of the produce of the Ceylon *Placuna* fishery also finds its way to China, but the bulk from Ceylon and Sind is consumed in India, either as a component in native medicines, or calcined to form a luxurious form of chunam to smear on betel leaf used in chewing, or as a cosmetic by native ladies. The value of the Sind produce is given as Rs. 15 per tola, the same rate as that current in Ceylon, where one rupee's weight (equivalent to one tola) of these pearls passes current at a similar price. Any exceptionally fine and large pearls are, however, taken out from the bulk and sold separately.

Before entering upon the detailed description of the anatomy and histology of this mollusc, it affords me great pleasure to acknowledge my indebtedness to two helpers, Mr. T. Southwell, A.R.C.S., and Mr. George Henry, whose skilled assistance was always most willingly given. Mr. Southwell was kind enough to prepare and cut a large series of serial sections of young individuals, and to help very considerably in working up this material, while the extent of Mr. Henry's help may be gauged by reference to the very beautiful drawings which add so much to the value of this paper.

To Mr. Edwin Wilson, Cambridge, I also tender my sincere thanks for the great care and skill he has bestowed in reproducing the drawings upon stone; the result is everything I desired.

THE SHELL.

The shell of *Placuna placenta* in the fully-grown condition is free, greatly compressed, and distinctly, though slightly, inequivalve. The outline is sub-orbicular, the longitudinal axis (length) to the vertical axis (height) being an average of $155\frac{1}{8}$ mm. to $142\frac{1}{4}$ mm. for a number of the oldest generation of these shells collected in Lake Tampalakam in 1905. Strangely enough, 155 mm. by 142 mm. were the precise measurements of the largest living specimen I have collected in the Gulf of

Kutch. Series of younger generations give almost practically the same ratio—in one case $114\frac{5}{12}$ mm. to 102 mm., and in another $125\frac{1}{5}$ mm. to 115 mm. We may, therefore, take the ratio of length to lateral height or depth as 11 to 10, both for adults and immature individuals.

This slight inferiority in the height is due to peripheral growth being largely arrested along the central portion of the dorsal line, where a linear hinge forms the junction between the two valves. In consequence, adult shells show a straight edge along the most dorsal region, measuring approximately one-fifth to one-fourth of the extreme length of the valves. This particular feature, however, may exhibit considerable variation; the hinge region in some shells may even assume an obtuse-angled outline.

The right valve is almost flat, the left slightly, but appreciably, convex externally. In many adult individuals the mid-posterior region of both valves shows a single wide shallow lateral depression or contortion, extending some distance inwards from the margin, and with its convex aspect to the left side of the shell. There is occasionally a similar but much less distinct bending in the mid-anterior region of the shell, *vis-à-vis* to the posterior one. These two lateral contortions exhibit a considerable degree of variation both in the extent or area in which they involve the valves and in their relative proportions. Thus specimens are seen where the anterior folding is larger than the posterior, and in others one or other may be practically non-existent.

Such contortion as is indicated here is developed to a maximum in *Placuna sella*, a large and massive species of distinct saddle shape, separated from *Placuna placenta* principally for this reason. In this connection it is interesting to see occasionally among old individuals of the latter species, instances where contortion is sufficiently well marked to exhibit suggestive approximation to weakly-contorted specimens of *Placuna sella*.

I have said above that the outline of the shell is sub-orbicular. So it is typically, but rather because of the inevitable damage to delicate shell growth that takes place from time to time as the shell increases in age, and which tends to remove more or less completely any thin outgrowths that depart from the circular outline.

In very young individuals of 2 cms. and thereabouts in diameter, the sub-orbicular form without any marginal outgrowths is normal, and such show the straight dorsal hinge line clearly, and a slight unbonar beak. In slightly older specimens, where the shell has attained a diameter of about 5 cms., it is found that the portions of the dorsal margin of the shell at each end of the hinge line begin to grow more rapidly than the rest of the margin, and thus form one or several rounded ear or wing-like lobes at either end of the hinge (Plate I., fig. 1). With the growth of the shell these ears may become very prominent, and attain a length of from one to two centimetres (Plate II., fig. 2, *a.e.*). Frequently in young shells two, or even three, of these "lobes"

may appear at the anterior end of the dorsal margin ; at the posterior end a single and larger lobe is usually developed. In rare and extreme cases one of these "ears" or lobes at each end of the hinge line, growing out at right angles to this line, becomes so pronounced that they include the hinge region in a deep bay. In adult shells these ear-like lobes usually become broken off, but remnants of them may generally be traced.

The anterior, ventral, and posterior margins of the valves in undamaged adults are typically entire ; such a margin is frequently seen in immature individuals, but a large proportion of the larger shells show irregularities due in the first instance to injuries inflicted by fishes. Plate I., fig. 2 (A and B), shows two extreme instances. In the former (A), several injuries of old standing are recorded in the irregular or "bayed" appearance of some of the old concentric growth-lines, while the ventral edge shows a large one of recent infliction, as indicated by the clearness of the edges of the semi-circular gap resulting from a fish's bite. As in the true pearl oyster (*Margaritifera vulgaris*), reparation of such injuries is extremely rapid, and so long as the bite affects no organs or tissues except the mantle edge, *Placuna placenta* possesses great recuperative powers. Such injuries have economic interest, as they constitute an effective and necessary factor in the life-cycle of the cestode and trematode parasites whose larvæ form the nuclei of many *Placuna* seed pearls.

The outer surface of the shell is marked by distinct concentric lines of growth, consisting of slightly projecting imbricate lamellæ, the margins of which are rendered minutely uneven or roughly dentate by the presence of numbers of short, closely set and very delicate processes, spatulate or finger-like in form, and rather ragged in their irregularity and wear (Plate I., fig. 2).

These concentric rows of minute processes impart to the shell a certain roughness to the touch ; they occlude many particles of mud, and this is apt to give the shell a dirty brownish colouring, and the false appearance of having a rough superficial periostracal investment.

The two valves of the shell are united dorsally by a short hinge ligament coincident with the greater part of the straight dorsal edge. On the dorsal edge the ligament is straight, while on the ventral two very long linear projections, and a number of short, narrow dentate ones are seen, corresponding in position and size with a similar number of projecting teeth arming the hinge line of the opposite right valve (Plate II., figs. 2 and 3). So relatively strong is the ligament that a small portion of the dorsal margin of the right valve is usually broken off, and remains attached to the ligament when the valves are forcibly separated.

In very young specimens the hinge ligament is dark golden brown ; with age the colour deepens, till in the fully mature it becomes a brownish black with a bronze green lustre.

On the right valve two very prominent cardinal teeth arise close together at the

central point in the hinge line. They are long, narrow, and greatly compressed laterally ; they run ventrally, diverging as they go. The posterior is considerably the longer of the two, measuring over 2 cms. in fully-grown shells, whereas the anterior is but 1·5 cms. long. These teeth have their free edges slightly rolled or curved outwards upon themselves in such a way as to give the ligament a very secure grip (Plate II., fig. 1).

A number of minute teeth occur on each side of the cardinal projections and parallel with them, so that those in front of the anterior cardinal tooth run anteriorly and ventrally, and those behind the posterior cardinal, towards the posterior and ventral aspects. Frequently one, or, less frequently, two minute teeth occur between the cardinals.

All these small hinge teeth alternate with papilliform terminations along the dorsal aspect of the mantle ; in young specimens, up to 2 cms. long, they are absent.

In the three spaces or pockets formed by the cardinal teeth and their ligaments, lie three corresponding dorsal portions of the mantle.

The internal surface of the valves is smooth, with a high polish. The impression of the single adductor muscle is situated sub-centrally, a trifle dorsal to the centre, and is very noticcable. The minute insertion scar of the single pedal levator muscle may usually be seen upon the left valve, a little posterior to the ventral extremity of the anterior cardinal hinge ligament.

No well marked pallial line, such as we have in *Cardium* and *Mactra*, nor a regular series of scars caused by the insertion of the pallial muscle bundles, as seen in the true pearl oyster (*Margaritifera vulgaris*), can be distinguished. The only vestiges of such are two or three narrow and elongated faint scar-impressions, a little anterior to the antero-ventral corner of the adductor scar, and two others of smaller size at a corresponding level behind it. In adult shells the map of the pallial muscles is conspicuous as a fan-like radiation of shallow grooves ; all the main bundles have their corresponding impressions on the inner surface of each valve.

The shell in young and immature individuals is very thin, transparent, and usually colourless, whence comes its popular name of window-pane oyster. When fully grown the shell attains a thickness of about one millimetre, and losing its transparence becomes sub-opaque, white, and somewhat friable, suggestive of dull white mica which has lost its transparency through weathering.

The substance of the shell is composed of the same three layers as are characteristic of most Lamellibranch shells, but here the organic basis is unusually well developed, while the periostracum, or superficial horny layer (seen well in *Unio* and *Arca*), is exceedingly thin and scarcely discernible even in young specimens, where it can scarcely yet have been worn off by attrition or decomposition. In old specimens the middle or prismatic layer becomes actually superficial, although the mud which lodges in the roughness of the outer surface of the middle layer gives, as already mentioned,

a false appearance of a well-developed periostracum. Thorough washing, however, reveals the mature shell to have no superficial horny layer, and to consist of two layers only, the outer sub-translucent and with a micaceous cleavage, the inner transparent in younger specimens and sub-translucent with a marked pearly white lustre in older ones.

That a delicate periostracum is actually secreted is shown distinctly in sections through the mantle edge, where, as in Plate V., fig. 32, a delicate horny secretion (*periost.*) is seen in process of formation by cells situated at the base of the periostracal groove exterior to the true pallial margin (*mg. p.*).

GENERAL ORGANISATION.

In proceeding to a dissection of *Placuna* it is preferable to begin by removal of the left valve, as the visceral mass and the majority of the organs are fused with or sunk in the right mantle, whereas the left has retained very largely its primitive character of a thin membranous fold serving as a loose envelope or cloak to the remainder of the body.

When the left valve is removed, this left mantle is seen to have lined the inner surface of the valve except at a sub-central spot where one end of the large adductor muscle (*add.*) pierces the mantle to find insertion on the inner surface of the shell, and at the few small scars made by the insertion of the pallial muscles.

The mantle edge is seen to be free at all points save dorsally along the hinge line, where the two mantle folds meet and fuse. This dorsal union is complicated by the intrusion of two enormous cardinal teeth (*c.t.*) with their ligaments, which entails this dorsal region being split up into three portions—the central, bounded on either side by a cardinal tooth, being conical in outline, while the two lateral are broadly spathulate, and wider on the dorsal or free edge than at the base where they merge into the rest of the mantle (Plate III., fig. 19).

The dorsal edge of these lateral lobes in its turn is further subdivided into minute spathulate processes, sometimes slightly bifid at their extremities, which alternate with the minute hinge teeth found on either side of the cardinals.

A small portion of the gonad penetrates these same lobes.

Removal of the unattached portions of the left mantle exposes the visceral mass, foot, labial palps and gills (Plate II., fig. 4). The first three lie on the side dorsal to the adductor, while the gills beginning a little way above the anterior aspect of this muscle pass first forwards and downwards, and then posteriorly along its margin in such a way as to bound it on two sides. The visceral mass occupies the space between the hinge and the adductor muscle. Broad and tumid ventrally, it narrows somewhat dorsally, giving off on that aspect two thin lobes to the anterior and posterior pallial hinge flaps.

Projecting forwards from each side of the anterior aspect of the visceral mass is a pair of lamellar palps (*Pa.*) as in other Lamellibranchs. In *Placuna* they are greatly elongated dorso-ventrally and narrow relatively to their length. The opposing faces of the members of each pair are deeply grooved transversely, and clothed with ciliated epithelium. In common with the majority of organs in this species, the palps are asymmetric, due to the mouth being placed to the right side of the median line. As a consequence the upper and lower lips, which normally are prominent transverse folds connecting the dorsal and ventral (outer and inner) palps of either side respectively, are here twisted to the right, and come to assume rather a vertical than a transverse position. The ventral margin of each inner palp bends inwards below the insertion of the foot, and unites in the median line with its fellow from the opposite side.

The anterior tip of each ctenidium or branchia is led into and attached to the base of the gutter formed by approximation posteriorly of the bases of the two palps of its respective side. Beginning from this attachment each ctenidium is suspended throughout its length from a wide mesentery, attached along its inner margin for a short extent anteriorly to the kidney, and for the remainder and greater extent to the mantle close to its junction with the adductor muscle in the case of the left mesentery, and along the course of the stylar (ventral) visceral lobe in the case of the right ctenidium.

Cutting away the gills and their suspensory membrane or mesentery close to the adductor muscle, together with the left pair of palps, we are enabled to see clearly how greatly interpenetrated is the substance of the right mantle by various lobes of the visceral organs. Beside the two hinge-lobes already mentioned, the principal of these are three in number, which may be termed respectively the posterior genital, the rectal, and the stylar lobe (Plate III., fig. 13).

The first of these is an elongated, somewhat wedge-shaped tumid mass (*Go.p.*), having its long axis directed obliquely posteriorly and ventrally; a deep groove marks it off from the posterior margin of the main visceral mass, connection being made by a narrow bridge of tissue dorsal to the apex of the ventricle.

The rectal lobe lies ventral to the last named; it runs obliquely backwards from the mid-ventral region of the main visceral mass at an angle of about fifty degrees from the vertical, and terminates a little above and beyond the posterior extremity of the gills. For part of its course it is attached ventrally to the surface of the adductor muscle, while near its distal extremity it is approximated to the ventral end of the posterior genital lobe, to which it is connected by a very narrow and inconspicuous bridge of tissue. The rectum lies for most of its course within this rectal visceral lobe; at its posterior extremity the anus opens in the centre of a wide and shallow funnel (*An.f.*, fig. 5).

The third visceral lobe is peculiarly interesting, as although it has no great bulk its length is relatively extreme. Its position may be defined as parallel and coincident

[*Photo by Viridha Kala Mandir, Baroda.*

Anatomy of window-pane oyster as seen after the removal of the left valve and mantle, showing the fine strands of the pallial muscles and the deeply pigmented ventral pallial sinus within the right mantle, the gills, adductor muscle, foot, cardinal hinge teeth, etc. Part of the pallial sense organ shows just under the posterior tip of the gills. The great extent of the branchial mesentery is conspicuous, and the outer accessory fold of the reflected branchial lamella is discernible. Two small pearls are seen *in situ* close together in the ventral region of the mantle. × $\frac{3}{4}$

[*To face p.* 56.

with the direction and extent of the gills. It arises from the anterior ventral angle of the visceral mass close to the lower margin of the palps, and extends thence in a semi-circular and gradually narrowing band to a point midway between the anus and the hinder limit of the adductor muscle. Embedded in it, and showing through it for a considerable part of the distal portion, is the enormously long crystalline style.

The ventricle of the heart lies free within the angle made by the upper margin of the rectal visceral lobe with the posterior edge of the visceral mass. As the posterior genital lobe lies athwart the base of the angle so formed, an imperfect chamber—the cardiac chamber—is formed, open, be it remembered, on the left lateral face. No trace of pericardium is to be seen.

The foot (*F.*) is attached to the anterior surface of the visceral mass between the two pairs of labial palps at about the level of the lower half of their length. The attachment of the anterior extremities of the gills is distinctly ventral to the base of the foot; in the pearl oyster (*M. vulgaris*) the apices of the gills bound the foot laterally.

In *Placuna* the foot reaches a high degree of specialisation; it is extremely mobile, and capable of great extension and equally great contraction. The form assumed is that of a cylinder much flattened laterally. The apex is modified to form a well-developed deep cup-shaped sucker with strongly developed muscles in the rim; in contraction the edges of the sucker are approximated, obliterating the cavity more or less completely.

Within the walls of the sucker muscle fibres radiate from the centre of the pedal axis. It would seem from this structure that the mechanism is similar to that of a boy's leather sucker—when the rim be everted and the surface of the cup applied to a flattened surface, a vacuum will be created by the contraction of the radial muscles. Were *Placuna placenta* to live on stony or rocky ground, this arrangement would suggest that the animal employs this organ in locomotion to drag itself from object to object. On the mud flats where it lives, this function cannot be employed. From this consideration, and from observations made on the animal in an aquarium tank, it seems to me that the principal use—if indeed it be not the sole one—the foot here subserves is that of a cleansing organ.

In dissection the sucker cavity is usually found to be gorged with mud; where *Placuna* lives the water is normally turbid with mud and flocculent vegetable debris in suspension. The animal must have an organ to collect and clear away the foreign matter which is continually settling and accumulating upon the surface of the mantle and gills, and lodging in corners and cavities; an extremely extensible and flexible cylindrical organ, bearing at its extremity a muscular sucker-cup armed with a highly sensitive and mobile rim, is ideal for such purpose, and this appears to be the purpose to which the foot is put by the window-pane oyster.

In a normal state of contraction, when this organ is at rest, it measures not more

than 1·75 cms. in diameter. What the maximum may be is difficult to say in respect to fully adult animals, but I have note of an instance where on opening a living specimen suddenly, and with a minimum of shock, the foot was seen to be bent downwards, and to lie along the ventral side of the adductor muscle with the sucker approximated to the anus. In this state of extreme extension it was somewhat reduced in diameter; the length was slightly over six centimetres.

The substance of the foot is composed of networks of muscle fibres running in various directions, the principal being longitudinal and radial. Others again are disposed concentrically, and by these various series the foot can be deflected as required.

A weak levator muscle (fig. 4, *Lev'.*), difficult to discern without the aid of serial sections, originates in the upper portion of the pedal base, and assists in retracting the foot upwards, its insertion being in the left valve posterior to the ventral end of the anterior cardinal tooth, while a similarly weak muscle bundle passes from the ventral pedal base to the upper surface of the adductor, and is therefore the homologue of the powerful retractors seen in *Margaritifera*. In *Placuna* a single bundle alone is traceable, its insertion being in the left valve at the anterior dorsal corner of the adductor muscle (fig. 31, *Ret.*), as is also the case with the two retractors present in *Anomia*.

Sections of partially extended feet show the muscular framework to be so extensively penetrated by blood cavities as to be highly cavernous. Injection of these spaces with blood produces extreme inflation or turgescence, which, as seen, enables the organ to attain an elongation at least four times that of the contracted condition, and in conjunction with the complex of muscles composing it and acting upon it, provides for all the varied movements of which the foot is capable.

The blood supply is derived from a stout artery given off from the anterior region of the hepatic visceral artery. Blood passing from the foot enters the left visceral sinus and passes to the kidneys and thence to the gills.

The nerve supply to the foot comes from the pedal ganglion, which is situated close to and practically within its base on the dorsal side. A single nerve trunk is given off which ramifies throughout the tissue of the foot in a most complete manner

Both byssus and byssal gland are absent, neither is there any trace of an otocyst—the latter a peculiarity shared with *Solenomya* and a few other Lamellibranchs.

The inner surface of the pedal sucker appears to be homologous with the locomotor region of the foot in *Margaritifera*: whether the byssal gland is also represented by the interior of the sucker cannot be decided until we obtain embryological light upon the subject.

PALLIUM OR MANTLE.

The general disposition of the mantle has already been noted. We have seen that its borders are without sutures between themselves save for a short distance along the hinge line, where the two pallial lobes unite over the extreme dorsal region of the body. The margins of the lobes are otherwise absolutely free; they show no trace of siphons, neither are the branchiæ connected laterally with the inner surface of the mantle either by organic fusion as in *Anodonta*, or by ciliar suture as in *Margaritifera vulgaris*.

Three regions compose each pallial lobe—a central, a distal or muscular, and a marginal, all comparable and closely related in structure and position with the similar regions seen in the mantle of *Margaritifera*.

The central pallial area extends from the mid-dorsal line to the irregular and imperfect pallial line where are inserted the radiating pallial muscles. The junction with the distal area is not demarcated clearly as in the case of Meleagrinidæ. The greater portion of the central pallial area is adherent to the visceral mass on both sides, and a comparatively small part is free.

In both cases the mantle is thin and transparent, except where in the right mantle masses of reproductive tissue and portions of the alimentary canal penetrate and ramify in its substance.

Where free from the complication of adhesion to the visceral mass, or of penetration by glandular and other organs, the tissue consists of two parallel sheets of epithelium connected by an excessively fine network of connective tissue.

The distal or muscular region of the mantle is transparent save where masses of black pigment occur in the external superficial tissue. The whole of its external face is covered with secretory epithelium similar in histological structure to that upon the exterior of the central pallial area. Below this outer epithelium occur a few scattered glandular cells of large size, and containing slightly refractive granules.

Strongly ciliated epithelium lines the inner surface of this pallial region and subserves the double purpose of assisting in maintaining a steady indraft of water into the branchial chamber and in ridding the pallial surface of sediment brought by the incoming water current. In *M. vulgaris* a distinct narrow marginal ciliated "path" exists, along which pellets of sediment are propelled to the exhalent region; here there is no such path—the whole ciliated surface acts this part. In a newly-opened living individual tiny pellets of mud may be seen at several points on the general inner surface being propelled posteriorly, to be swept from the body by the current of the excurrent stream of water from the gills.

Histologically there are present the usual characteristics of this region as seen in other Lamellibranchs—a filling of connective tissue fibres in which radiate fan-shaped muscle bundles, the trunks and bundles of the pallial nerve plexus and a great network

of irregular communicating blood spaces. One of these last is developed into a well defined and most conspicuous channel, the anterior ventral pallial sinus (fig. 19, *Sn.pall.a v.*), which, arising close to the posterior extremity of the gills by the confluence of several smaller sinuses, passes forwards and upwards, adjacent to and parallel with the course of the axes of the gills, to near the base of the foot where the sinus opens into the common branchio-cardiac trunk. This great sinus is accompanied through the greater part of its course by a nerve trunk and by a rich black pigmentation in the epithelial cells of the outer surface. It receives branch vessels at intervals from the substance of the mantle and the main ones are also outlined in pigment.

It is noteworthy that the course of this pallial sinus and its main feeders, together with those of the principal radial bundles of pallial muscles, are clearly impressed as well-defined shallow grooves upon the inner surface of each valve.

In the mantle fold on the right side of the body a further complexity is introduced into this region by the necessity forced upon it to provide accommodation for the enormously developed pyloric caecum (*C.st.c.*) and its huge crystalline style (*C.st.*), which, with a narrow enveloping sheath of genital tissue, penetrates the pallial tissue in a great semicircle parallel with and slightly dorsal to the median pallial sinus, ending a short distance anterior and ventral to the anus. Its termination coincides with the position of the free dorsal edge of the right branchial mesentery.

As in other Lamellibranchs, each pallial lobe terminates in a thickened muscular rim or margin pleated longitudinally into three folds throughout the whole length (fig. 32). The two outer folds form the true pallial margin; they project outwards in the same plane as the shell, while the third or inmost fold, the velum or "veil," lies at right angles to the other two and as an inwardly directed narrow shelf of tissue on the inner side of the mantle. When the valves are slightly open these velar folds, with their delicate digitate processes, extend inwards towards each other in the middle line and thus form a highly sensitive strainer guard, ever ready to give instant warning of contact with any would-be intruder.

Of the two folds forming the true pallial edge, the outer may be called the secretory fold, the inner the sensory. The former lies in contact with the growing edge of the valve kept tightly adpressed thereto by a film of cuticular membrane, the periostracum or epicuticula (*periost.*). This arises from the secretion of a layer of glandular epithelial cells lining the base of the groove separating the outer from the inner fold of the pallial edge. Fig. 32 shows how this structureless membrane curves outwards and is reflected over the free edge of the shell, firmly attaching the secretory marginal fold thereto. In this animal this function—the binding or securing in place of the secretory fold to the margin of the shell—appears to be the sole duty of the periostracum, as it appears not to persist over the general surface of the valves in adult individuals.

The sensory fold between the velum and the secretory fold of the mantle edge is very similar in general appearance to the velar edge, but is furnished with more numerous simple unbranched digitate processes. These are highly contractile and extremely sensitive.

Along the base and in the connective tissue filling of the thrice-folded pallial margin runs a peripheral blood-vessel, the pallial artery; with it, in intimate association, is a strong nerve trunk, giving off a multitude of fibrils to the secretory and tactile areas. The ultimate twigs of the pallial muscles penetrate to this margin, enabling retraction to be effected upon any irritation experienced by the sensory cells in the vicinity. The greater the rapidity of retraction the greater the immunity from damage by predatory fishes and other enemies. Large spaces or sinuses are very conspicuous, penetrating the loose connective tissue which is freely developed close to the mantle edge.

We have already noted that the continuous growth of the periostracum functions to keep the margin of the mantle attached to the edge of the shell. The mantle is further kept in position lining the valves by the adhesion occasioned by the formative secretion of the cells of the external surface. Violent contraction of the pallial muscles impairs these two mechanical adhesions by dragging the mantle edge away from the margin of the shell, while the distension and turgescence of the mantle with blood coincident with relaxation of the pallial muscles permits the contracted mantle to re-spread or re-expand over its normal and full area, when a short period of quietude re-establishes mechanical adhesion with the shell by new periostracal growth and surface secretion.

It is important to note the importance which the right mantle lobe assumes over the left in this mollusc, through the penetration and lodgment within it of the bulk of the reproductive gland, the great pyloric caecum and a considerable portion of the rectum.

Pigmentation.—The development and distribution of pigment in the mantle is very variable. In some cases practically the whole of the external surface is covered with black pigment. In other instances the colouring matter is less extensively developed; bands of pigment, however, invariably follow the course of the great median pallial sinus and its main branches, as well as that of the more important of the pallial muscle bundles. This black pigmentation is limited to the mantle, where it occurs in the superficial epithelial cells. Nowhere else is there any true pigmentation—the inner surfaces of the mantle and all the folds and processes of the mantle edge are colourless, a condition the reverse of what is seen in the true pearl oysters (*Margaritifera* spp.), where the mantle edge and the inner surface of the mantle are often profusely pigmented and where the outer surface of the mantle lying in contact with the nacre of the valves is invariably free from even the slightest pigmentation. The reason is not far to seek. It has already been noted that Ceylon

pearl oysters (*M. vulgaris*) found living in shallows—say under one fathom in depth—are usually much more brightly coloured with black and orange over the mantle, gills and foot than those from depths of seven to eight fathoms. We also know the general tendency of continued exposure to bright light to encourage the development of pigments, usually dark in hue. Hence, as *P. placenta* is essentially an inhabitant of shallow waters, where light is intense and long-continued, we can readily understand the cause of extreme pigmentation of the mantle. As to the less obvious reason for it being on the exterior of the mantle instead of the interior, as in *M. vulgaris*, this is most probably due to the transparency of the valves. In the true pearl oysters the valves are opaque—the sun's actinic rays cannot penetrate their substance—hence no protection need be given from this aspect to the delicate organs and tissues, nerves especially, lying beneath. Protection has, however, to be given against light entering between the open edges of the shell, hence development of pigment on the gills and the *inner* surface of the mantle.

In *Placuna* the valves are transparent, and, as light passes through them without difficulty, protection must be provided against light impinging directly on the mantle from the exterior—effected, as we have seen, by a development of black pigment either generally over the exterior of the mantle or restricted to the course of the main trunks of the pallial nerve plexus.

THE MUSCULATURE.

Like the pearl oyster, *P. placenta* is monomyary, a single adductor, the posterior, being present. The other muscles are relatively weak, and consist of:—an unpaired weak levator of the foot, a similarly unpaired weak pedal retractor, an imperfect orbicular pallial muscle, branchial cords, and the heart or cardiac muscle. (The last will be treated of separately when describing the vascular system.)

The Adductor Muscle of the shell is situated sub-centrally, stretching transversely from valve to valve midway between the anterior and posterior limits of the shell, but slightly nearer the dorsal than the ventral margin (fig. 4, *Add.*). It is the only large muscular mass in the body, and is by far the most important. The outline in section is circular, while the diameter in specimens of 14 cms. long is about 2·3 cms.; the length is inconsiderable in consequence of the extreme lateral compression of the valves. It lies ventral to the visceral mass; the surface of the dorsal half is closely embraced by the renal organ. Along the posterior border runs the terminal section of the rectum, while upon the antero-ventral curvature rests the parieto-splanchnic ganglionic mass.

Even a casual observation in the living condition reveals the fact that this muscle is not homogeneous; in preserved specimens the fact is emphasized; two distinct regions are visible to the naked eye—a posterior and median, and an anterior and

larger surrounding the former except on the posterior aspect. The posterior section may be said to be sunk in the anterior one (fig. 9).

The posterior component in most preserved specimens retains a darker colour than the other and larger region ; it extends forwards from the posterior margin of the mass for about three-fourths of the diameter of the entire adductor, and so is covered dorsally and ventrally by arm-like prolongations of the anterior region. Little histological difference can be noticed between the elements of the two sections except that the fibres of the anterior appear rather finer, and are aggregated into larger and more densely compacted bundles than is the case with those of the posterior. The muscle bundles round the periphery are large and wedge-shaped in section ; those of the centre small and rounded. Both the component masses are freely permeated with blood spaces more numerous, however, in the hinder section of the muscle. In *Pecten* the fibres of the anterior component show an appearance of striation ; here no indications of this could be perceived in sections—the fibres of both regions appear quite smooth.

The blood supply is derived from the posterior limb of the aorta through one artery entering the adductor on its upper surface and by three others entering between the halves of the parieto-splanchnic ganglion (fig. 15). Innervation is directly from the ganglion just named, whence two trunks arising side by side from the two halves of the mass pass immediately into the substance of the muscle, dividing as they go into small twigs (fig. 10, *N.add.* and fig. 29, *Par.sp.g.*).

The Levator Muscle of the foot is weakly developed in *Placuna;* it consists of a narrow band of muscle fibres inserted obliquely in the left valve immediately posterior to the ventral extremity of the anterior hinge tooth (fig. 19, *Lev'.*). Thence the fibres pass vertically downwards, spreading laterally as they approach the base of the foot, where they blend with the intrinsic pedal muscle fibres. A similar reduction of the pedal levators to an unpaired weak bundle inserted in the dorsal region of the left valve is met with in *Anomia.*

The Pedal Retractors are similarly reduced in *Placuna* to a single fairly stout bundle, which arises from the ventral part of the muscular base of the foot and passes downwards to the left side of the dorsal surface of the adductor, where it finds insertion upon the left valve (fig. 31). In *Placuna* this muscle has little importance owing to the absence of a byssus ; large development of the pedal retractors appears to be correlated with special development of a byssal organ. As examples we have two powerful retractors present in *Margaritifera vulgaris,* where a many stranded byssus exists, while in *Anomia,* where the byssus undergoes modification into a great calcified organ, these muscles are still larger and more important, with the unique peculiarity of being both inserted in the left valve in like position as the single one in *Placuna.* In view of this special function these muscles might with greater propriety be termed byssal, and not pedal retractors.

The intrinsic muscles of the foot form an extremely complex system, comparable in general arrangement with the musculature of any mobile liguliform muscular organ. Towards the base the fibres in large measure radiate outwards to form a somewhat laterally compressed discous base. In the cylindrical trunk region of the foot the muscle fibres run in every possible direction; many run longitudinally, some run circularly, others radiate outwards, and the remainder interlace in apparently hopeless confusion. Circular and radiating muscle fibres preponderate in the sucker-like free extremity; the rim is capable of closure as by a sphincter muscle.

Few other intrinsic muscles are to be found in *Placuna;* the principal are the small paired cylindrical muscle bundles which traverse the axes of the branchiæ longitudinally in the floor of the efferent branchial vessels (fig. 24).

Slender muscle fibres also pass down the interior of the individual gill filaments, enabling them to be retracted to some slight extent.

The Orbicular Pallial Muscle is composed of a small and variable series of loosely compacted fan-shaped muscles radiating outwards to the mantle edge from some four to six insertion centres of varying size and shape grouped in a roughly semi-circular manner around the ventral half of the adductor muscle. The disposition of these centres (and of the corresponding scars which their insertion imprints upon the inner surface of the valves) lacks alike the regularity of disposition seen in the Meleagrinidæ, or the continuity characteristic of *Cardium;* the insertion scars are extremely faint on the valve surface in *Placuna*, while in a dissection the insertion centres are difficult to trace owing to their irregularity and to the layer of reproductive tissue which accompanies and masks them. One of the most frequent dispositions is where there are two large insertion centres anterior (*M.ins.a.*) and two small ones posterior (*M.ins.p.*) to the base of the adductor, with a long and extremely narrow band insertion skirting and apparently fused with the ventral edge of the adductor at its insertion in the valve. Fig. 19 graphically depicts the relative positions and forms of these centres, as well as the course and branching of the ill-defined fans of fibres which radiate towards the pallial margin dividing into finer and finer branches as they go.

From the radial course pursued by these bundles, it follows that they are attached to the shell at a very acute angle. Their whole course lies in the filling of connective tissue forming the thick middle layer of the distal region of the mantle. Many of the branches anastomose, and as they approach the pallial edge they divide into two sets of fibres, one passing to the inner aspect of the margin to provide for the movements of the velum, the other to the outer margin to serve the two folds of the true pallial edge. Many of the principal of these radial muscles impress a record of their course and branching in corresponding shallow but distinct groovings upon the inner surface of the valves.

THE ALIMENTARY CANAL.

The alimentary canal in *Placuna* consists of a slit-like asymmetric mouth, a rather long and wide œsophagus, a capacious stomach surrounded by a well developed digestive gland, an enormously developed pyloric cæcum, a short intestine making a single visceral loop, and a short and slightly curved rectum ending in an anal opening in the centre of a broad and widely everted membranous collar (fig. 14).

The mouth is a long slit-like aperture situated vertically in a deep cleft between two delicate membranous folds—the lips or labia—to the right side of the median plane of the body at about midway between the base of the foot and the dorsal margin of the body. The mouth is concealed by the labia. These, which in typical Lamellibranchs are disposed transversely to the vertical plane of the body, here follow the asymmetery of the mouth; what is morphologically the lower one in *Placuna* bounds the mouth along the left side; the upper lies to the right of the mouth. At each angle of the mouth the labia close in and pass into the labial palps. The labia are smooth on both surfaces; the labial palps are smooth on the faces turned away from each other, while on those turned to one another they are furrowed with many fine transverse ciliated furrows of ordinary typical form such as seen in *Margaritifera*. The free edges of the labial palps face forwards (anteriorly) while the posterior margins are attached to the front of the visceral mass. Those of each pair are also closely approximated at their insertion into the visceral mass, forming thus a very narrow deep-walled gutter along which food pellets are propelled by ciliary action from the anterior extremity of the gills to the corners of the lips and thence into the mouth.

Unlike the labia which are thin and membranous, the palps are considerably thickened with a filling of connective tissue. They are unusually long, reaching well below the base of the foot. The ridges are of the same form as seen in *Margaritifera* and densely ciliated.

The mouth leads into a long and rather wide ciliated œsophagus, slightly compressed laterally, which curves posteriorly and ventrally and opens abruptly without change of calibre into the anterior dorsal region of the stomach.

The stomach is relatively capacious and occupies a sub-central position in the visceral mass. In form it is irregularly ovoid and much compressed laterally; its long axis lies somewhat obliquely dorso-ventrally in such fashion that the ventral part is directed slightly anteriorly, while the dorsal exhibits a corresponding backward inclination.

Several well marked depressions occur in the walls of the stomach, so that we may roughly divide it into four subsidiary chambers (*vide* fig. 29); the first is shallow and lies dorsal and anterior; into this the œsophagus opens. The second

is dorsal and posterior, narrow and cæcal in appearance and reaches a higher level dorsally ; the third is posterior and the fourth ventral and pyloric. The two latter chambers are very distinctly defined ; the posterior one, which may be termed the biliary chamber, is a deep branched crypt pushing its branches deep into the substance of the digestive gland from which it receives numerous large bile ducts. In the floor of the pyloric chamber two openings of about equal size are discernible ; the one leads into the intestine, the other into the pyloric cæcum (*C.st.c.*). From the latter opening the conical proximal end of the crystalline style (*C.st.*) projects some distance into the stomach ; a bolus-like mass of partially digested material may often be seen agglutinated upon this stylar projection.

This cameration of the stomach has the effect of considerably increasing the surface area ; in *Placuna* the stomach appears to be developed at the expense of the intestine.

The whole of the stomach is lined with ciliated epithelium, exhibiting great variability in the height of the cells. Usually these cells reach their greatest development on and over the permanent ridges. A delicate and easily detachable gelatinous layer—the *flèche tricuspide* (fig. 23, *Fl.tri.*)—invests a great part of the stomach wall ; wherever this layer is well developed, there we find the epithelium greatly elongated. This peculiar investment is particularly thick over the central anterior wall of the stomach, where it is intermittently adherent, dipping down between the ridges and pads which corrugate the inner surface of the stomach. No structure save a slight lamination can be detected ; it is perfectly clear and colourless—from its behaviour under reagents it appears closely related in composition to the crystalline style.

The stomach is almost entirely surrounded by the digestive gland. Only over the right aspect and at the extreme dorsal extremity does the investment fail ; in these regions, owing to the laterally compressed form of the animal, the wall of the stomach is separated from the mantle only by thin discontinuous patches of glandular tissue.

The "liver," or digestive gland (*D.gl.*), is a large, dense, acinose gland of sage-green colour, forming the greater part of the tissues of the visceral mass and forming a nearly complete investment to the stomach, œsophagus, and the proximal half of the intestine. Superficially, a considerable portion is covered in its turn by a thin sheet of reproductive tissue.

Bile ducts emptying the secretion of the digestive gland into the stomach are numerous (fig. 29, *D.gl.d.*). At least eight terminal ducts can be traced ; they are the following :—

(*a*) The dorsal duct opening high up in the postero-dorsal chamber.

(*b*) The anterior duct leading from the anterior region of the liver into the antero-dorsal chamber ; and

(*c*) A series of six which open into the well-defined, deeply indented biliary chamber in the hinder wall of the stomach. These ducts come from the posterior and ventral regions of the digestive gland.

The ciliated epithelium of the walls of the stomach is continued a considerable distance along the larger bile ducts (see Plate V., fig. 28). The gland proper is composed of dense masses of secreting alveoli, lined with large cells differing considerably in size and shape. Details are practically identical with those of such other Lamellibranchs as *Ostrea*, *Margaritifera* and *Cardium*, and therefore do not call for further detailed notice.

The Crystalline Style has already been noted as projecting somewhat into the pyloric region of the stomach. Its sac, the pyloric cæcum, is wholly free from any connection or fusion with the intestine along its entire course, thereby agreeing with those forms typified by *Mytilus*, *Donax*, and *Anomia*, as well as with such gastropods as *Pterocera*, *Trochus* and the *Fissurellidæ*.

From their respective proximal ends the pyloric cæcum and intestine immediately diverge, the former pursuing an anterior direction, while the latter in the first part of its course curves posteriorly.

The pyloric cæcum (*C.st.c.*) bends to the right and penetrates the right mantle almost immediately after leaving the stomach, and close to the anterior apices of the gills. It then passes forwards and downwards just in front of the adductor muscle, turns backwards at its antero-ventral curvature and then passes posteriorly parallel with and to the dorsal side of the pigmented line of the median pallial sinus (fig. 13). The blind termination coincides closely with the level of the normal position of the posterior apices of the gills—indeed, the curvature of the pyloric cæcum runs parallel with the gills throughout their entire length. From its mid-length to its termination the sac narrows very gradually. In preserved specimens, which naturally suffer from muscular contraction, the sac assumes a wavy or slightly sinuous course; in the living state the sac lies in a single unbroken deeply bow-shaped curve. Throughout its course the cæcum is embedded in an investing covering of reproductive tissue, of which a peculiar spongy tissue constitutes the major portion. In section the sac is perfectly circular throughout its length; its lumen is entirely filled by the colourless glassy substance of the crystalline style. In serial section of fixed material the style exhibits great shrinkage and occupies but a small portion of the cæcal cavity. No structure is discernible save a faint concentric lamination, giving the impression that the style is formed by the deposition of successive concentric layers of secretion.

The inner surface of the stylar sac is ciliated like all other parts of the alimentary canal, but the cilia are quite different from the ciliation of the other regions. They are characterised by being markedly strong and densely set; they are extremely stiff in appearance and are all of even length (fig. 25).

In their enormous relative length the crystalline style and its sac attain a development most remarkable—a development almost unique among Lamellibranchs. Only in *Anomia* do we find the cæcum so extremely elongated relatively to the other sections of the alimentary canal. In *Anomia* we may also note that the inner curvature of the cæcum is turned away from the adductor, so that the cæcal or distal termination is near the anterior edge of the mantle, whereas in *Placuna* the curvature of the cæcum embraces the adductor and its distal end is situated a short distance from the anus.

Regarding the function of the crystalline style, I am fully convinced from a study of this organ in the present species and in the pearl oyster (*M. vulgaris*)[1] that Barrois' view is correct, that the style is a cuticular secretion which serves to invest diatoms, sponge spicules and the like with a viscous coating which will secure the intestinal walls from damage through abrasion. The extreme length of the style in *Placuna* shows it to be of extreme importance in the economy of this mollusc; it is to be correlated with the particular habitat favoured—muddy bottom and slightly brackish water—both conditions which are well known to be most favourable to the growth and multiplication of diatoms, many of which, like *Navicula*, have sharply pointed siliceous tests that would abrade the delicate wall of the molluscan intestine unless some viscous investing substance were provided to form them into bolus-masses and serve as a lubricant during the passage through the gut. The stomach contents of *Placuna* bear this out; there is a predominance of diatom tests over other recognisable organisms—a much greater relative abundance than is seen in the case of the stomach contents of the pearl oyster.

The intestine arises from the lowermost section of the stomach, close to the mouth of the pyloric cæcum and somewhat to the right side. It passes for a short distance posteriorly and ventrally, and then, just anterior to the heart, it turns in a dorsal direction, curves forward, and then passes downwards when near and at the level of the biliary chamber of the stomach. This descending limb of the intestine crosses the ascending limb on the left side, thus completing a single simple intestinal coil largely within the substance of the liver. For some little distance, however, the wall of this coil comes close to the surface of the visceral mass, and is obvious to the naked eye as an elongated clear patch. The ventral curve of the intestinal coil lies close to and just anterior to the heart.

From this spot the intestine, which may now be differentiated as the rectum, passes in a fairly straight course downwards and backwards along the postero-dorsal curve of the adductor, then turns more distinctly in a posterior direction, bends slightly upwards, and opens on a flask-shaped anal papilla surrounded with a widely-everted membranous collar, and situated immediately dorsal to the distal extremities of the gills. On the upper or postero-dorsal aspect of the rectum is a cæcal prolongation of

[1] "Ceylon Marine Biological Reports," part ii., p. 78, Colombo, 1906.

the renal organ readily distinguishable even to the naked eye by reason of the dark colour of its glandular tissue.

The intestine is lined throughout its entire length with ciliated epithelium, and its absorbing area is considerably increased by the presence of a typhlosole or longitudinal ridge extending to the anus from about the first fifth of the intestine (fig. 26, *Ty.*).

Anteriorly the typhlosole when seen in section is somewhat mushroom-shaped, a narrow neck bearing a button-shaped "head." It is much less prominent and less expanded than in *Margaritifera vulgaris* in the corresponding region. Posteriorly it is even simpler, consisting of a simple parallel sided fold projecting into the interior of the rectum to about its semi-diameter.

In common with *Anomia* and *Arca*, the rectum is in no way attached or connected with the ventricle of the heart. It passes quite free on the anterior and ventral aspects of the heart.

BRANCHIAL SYSTEM.

The branchiæ are long and greatly curved, four delicately graved scimitars lying within the protection of the free portions of the mantle (fig. 4). From between the ventral edges of the labial palps the branchiæ curve first downwards and then backwards to a point just ventral to the anal aperture, where all four close together somewhat abruptly to a sharply attenuated conjoint free tip. In their course they keep parallel and a little inward to the mantle edge, the inner curve half circling the adductor muscle being suspended by two deep curtains of thin tissue, the branchial mesenteries, which hang from the renal tubes in the first part of their course, and in the hinder region from the mantle close to its line of junction with the anterior and ventral edges of the adductor muscle.

The four branchiæ or gills are disposed in pairs on either side of the body. As each pair constitutes a ctenidium, each branchia or gill is morphologically a hemi-ctenidium.

The ctenidia show comparative simplicity of structure. There is the usual longitudinal vascular base or axis along the inner margin of each ctenidium, upon which, on the outer face, are inserted two parallel series of long and delicate tubular outgrowths, the branchial filaments.

All the filaments being inserted at right angles to the axis on the outer face, their initial direction is outwards and towards the nearest section of the pallial margin. At a common distance from the vascular axis, filaments in each series change their course—those of the outer, or external, series are reflected or folded outwards upon themselves in the form of a V, with closely approximated wings, while those of the internal series are similarly V-folded, but in their case the folding is inwards (figs. 12 and 24).

Each series of filaments constituting a branchia is now seen to be divisible into

two lamellæ, the proximal or direct (fig. 12, *D.br.l.*), where the course of the filaments is directed outwards, and the distal or reflected (*R.br.l.*), where they are folded inwards.

The reflected lamella of the external hemi-ctenidium is rather narrower than the direct, due to the fact that this lamella, close to its distal margin, is again folded outwards upon itself to constitute a very small fifth lamella, a peculiarity very rare and seen only in the closely-related genus *Anomia*. In depth this accessory lamella (figs. 4 and 12, *Br.acc.*) is equal to the difference between the depth of the direct and reflected lamellæ. As in *Anomia*, the outer reflected lamellæ are free; there is no trace of concrescence with the mantle either by organic fusion or by ciliary junction. Along their whole length the distal edges of the reflected lamellæ of the inner branchial plates unite along the middle line in weak organic union, reinforced by a short ciliary concrescence on the ventral side of the organic fusion (fig. 12, *Ct.j.*), thus combining two distinct forms of concrescence and suggesting that the original form of union was entirely by ciliary concrescence as seen to persist—save for the merest thread of organic fusion—in the median branchial junction of the pearl oyster. The union along this median branchial line is continuous, fusing the terminals of all the filaments from the inner reflected lamella of each ctenidium into one continuous band of tissue and serving as a median support to the inner branchiæ.

The general arrangement of the filaments is of the Filibranch type. Except for the median branchial fusion, the filaments have no organic union between themselves; they lie perfectly free along their whole course save for a series of lateral interfilamental ciliated junctions just within the crest of each branchia where the direct filament passes into the reflected. At this place each filament presents an elongated swelling on each lateral face in such a way that the approximation of the two swollen opposing faces of the adjoining filaments reduces the space between them very considerably, a space bridged over by stout interlocking cilia borne upon each lateral swelling, thus constituting a ciliated disc (fig. 33). This development of ciliated discs along the free edge of each branchia is noteworthy and marks an advance in specialisation beyond what we find in *Anomia*, where true ciliated discs are wanting. As a consequence the branchial framework in *Placuna* has greater rigidity than in *Anomia*, the filaments less easily dissociated.

The vascular axis of each ctenidium, as before noted, is suspended from the mantle by a mesentery (figs. 4, 12, *Br.ms.*), extending from the base of the palps to the postero-ventral curvature of the adductor muscle.

The narrowed anterior apex of each gill is attached between the divergent ventral edges of the palps of its respective side. The extreme apex of the gill lies in the palpal gutter that marks the line of junction of the outer and inner palps, so that food particles passed to the anterior extremity of a ctenidium are caught by the palpar cilia and propelled upwards along this palpar gutter to the mouth.

In most Lamellibranchs the anterior extremities of the two ctenidia are separated for some distance by the base of the foot and the adductor portion of the visceral mass. In *Placuna* the palps extend to such a distance ventrally that the anterior apices of the gills are attached well below the foot and on a level with the ventral edge of the visceral mass (fig. 12). Hence the inner margins of the gills meet in the median line immediately ventral to the palps; save for this inconsiderable divergence the two ctenidia run conjoined throughout their full length. Anteriorly the pallial mesentery is short; it widens quickly, and for the major portion of its course is from two to three times the depth of the gills. In its posterior third it narrows slightly, while the combined terminal portion of the gills is free from its attachment for a short distance.

The axis of each ctenidium is hollowed out into a large irregularly tubular cavity, the efferent branchial vessel (*Br.eff.*), which receives purified blood from the filaments to convey to the trunk leading to the heart. In the floor of this sinus on either side runs a short muscular cylinder or cord, continuous from the anterior to the posterior apex of the gill. These two muscular cords function as branchial retractors, shortening the gills upon contraction and drawing them inwards, an action in which they are assisted by fine muscle fibres which radiate outwards within the branchial mesenteries.

Unlike the typical arrangement of parallel afferent and efferent vessels within the branchial axis, no second or afferent vessel is to be seen in the gill axis of *Placuna*. Such vessel is here represented by a well-marked longitudinal blood trunk running in the mesentery at some considerable distance from its base or attachment (figs. 4, 12 and 22, *C.br.aff.*). Connection between this vessel and the branchial filaments is effected through the intermediary of a network of sinal spaces (fig. 4, *Br.ms.pl.*) in the tissue of the mesentery; the arrangement is practically identical with that present in *Anomia*.

To understand the significance of this departure from the more normal arrangement as seen in such forms as *Margaritifera* and *Cardium*, it is necessary to recognise the mesentery as morphologically the proximal portion of the primitive ctenidial axis, a portion which has undergone a profound change of form; the conversion of a simple vascular ridge along the inner side of the axis into a deep sheet of tissue has induced a change from a system where extremely short channels connect a proximate afferent trunk with the individual filaments, to one where a complex and extensive network of ill-defined sinal spaces is intercalated between the filaments and a far removed afferent trunk. It would seem that the short afferent branches of the one have in part been modified into this peculiar sinal plexus.

The effect of this mesenteric development is to add materially to the blood-purifying area; it has a distinct accessory branchial function, and must assure a partial oxygenation of the blood stream prior to it passing into the gill filaments, thereby facilitating their branchial function. The very extensive development of the

mesenteries is to be correlated with the little depth characteristic of the gill lamellæ in *Placuna*.

The histological structure of the filaments is essentially the same as in *Anomia* and other forms where the branchiæ exhibit little specialisation. Each filament consists of a single layered cylinder of cells supported on a delicate basal membrane. In section the cylinder is seen to be somewhat club-shaped (fig. 34); the broader end morphologically is the ventral side, the narrower the dorsal. The cells of the former portion are very large, those of the narrow end exceedingly small and unciliated.

The majority of the cells on the broader portion of each filament are ciliated; certain stable distinctions in the distribution and character of this ciliation divide the ventral or exterior part of the filament into longitudinal tracts. A transverse section of a filament shows these to consist of—(*a*), a wide frontal ciliated tract comprising all cells facing directly outwards; the cilia on these cells are particularly short (*F.c.*); (*b*), at the antero-lateral corner on either side of the frontal tract, a single large cell bearing many much elongated cilia (*A.l.c.*), and containing a specially large nucleus; (*c*), a narrow bare region on either side of the filament, bounded outwardly by the ciliated "corner-cell," and on the inner aspect by the lateral cilia mentioned next; (*d*), a lateral ciliated tract (*L.c.*) several cells wide bearing long cilia, and (*e*), a few cells between the lateral ciliated tract and the margin of the small cells of the dorsal (internal) section of the filament. Fig. 34 makes clear this disposition of the ciliated tracts.

Beneath the epithelium of the filament a layer of connective tissue lines the cavity; for the most part this layer is thin, but within the narrow dorsal section of the filament it thickens and strengthens into two stout longitudinal skeletal bands (*Sk.b.*) to constitute a supporting framework against the collapse of the filamental tube.

As in *Anomia*, the cavity of the filament is divided into two somewhat unequal channels by an extremely delicate septum (*Sep.*) uniting the two skeletal thickenings towards the middle of the filament and situated rather nearer the narrower than the broader face.

The smaller or dorsal of these small vessels serves as an afferent (*A.ch.*), the larger or ventral as an efferent blood channel (*E.ch.*) through the filament.

At the distal end of each reflected filament these two channels communicate, the afferent passing over into the efferent, as the dividing septum does not extend quite to the extreme end of the filamental cavity.

Branchial Circulation.—As a consequence of the simplicity of the branchial plan, the blood circulation is for the most part of an equally primitive type. Impure blood from the body generally, after having bathed the tubules and pouches of the renal body, is collected into two well-defined vessels, the afferent branchial sinuses (figs. 4 and 15, *C.br.aff.*), one of which lies within each mesentery, entering

it close to the parieto-splanchnic ganglion. The vessel first passes outwards for about one-fourth the depth of the mesentery and then divides into a short anterior branch proceeding towards the anterior apex of the ctenidium and a long posterior branch which passes to the posterior extremity. Both branches keep well to the inner side of a line that would divide the mesentery into a proximal and a distal half.

From each of these vessels a large number of branches are given off which divide and ramify throughout the distal section of the mesentery to form an anastomosing network of sinal spaces (*Br.ms.pl.*). Along the outer margin of this plexus and fed by it, a series of regularly disposed and slightly swollen "capillaries" arise, which pass blood into each branchial filament. This current of blood flows outwards within the smaller or afferent of the two parallel cavities within the filament, returning by the larger or outer tube to empty into the wide efferent vessel running along the ctenidial axis (figs. 4, 12, and 24, *Br.eff.*). This vessel carries the blood forwards and upwards and is directly continuous with a short well-marked wide vascular trunk—the common efferent or branchio-cardiac vessel (fig. 24, *C.br.eff.*), running at right angles to the anterior portion of the branchial axis and connecting the anterior extremity of the ctenidium of its respective side with the auricle of the same side, appearing indeed as an anterior prolongation of the latter.

Oxygenation takes place partly during the flow of the blood through the mesenteric sinal plexus, partly during the flow through the branchial tubules.

Each ctenidium derives its nerve supply from a trunk which arises from the parieto-splanchnic ganglionic mass, and which runs within the mesentery some distance from and parallel with the ctenidial axis (figs. 10 and 11, *N.br.*).

Functions of the Branchiæ.—Apart from the oxygenating function which in *Placuna* as in *Anomia* is shared by the branchial mesenteries, the gills of *Placuna* serve two well-marked mechanical functions, (*a*) the capture of food particles, and (*b*) their conveyance to the mouth. The rhythmic lashing of the cilia clothing the outer faces of the filaments causes an indraft of water into the shell which not only serves to oxygenate the blood passing through the branchial tubules and mesenteries but ensures a continual stream of food particles being brought in. The close approximation of individual filaments and the fringes of cilia along their sides then come into play to intercept and strain out these particles, which are then caught up by certain cilia and propelled first to the crest (ventral edge) of the branchiæ and thence along this crest direct to the labial palps and mouth.

To properly perform these varied functions the cilia of the filaments have undergone specialisation and peculiar localisation. We have noted in each filament four distinct ciliated tracts marked off by the length and disposition of the cilia, (*a*) a broad

frontal band of short cilia, bounded by (*b*) a narrow band of long lashing cilia at each corner, (*c*) a lateral band of equally long cilia, and (*d*) close to the crest of the gill a ciliated disc on each lateral face of the filament.

The function of the last-named is to keep the filaments in position, to prevent them fraying out and becoming displaced. The short, stiff cilia of the "discs" interlock most securely and provide very serviceable unions between the filaments (fig. 33). The cilia of the lateral bands are not localised to one section of the filaments like the "discs," but stretch from end to end of the filaments; they are very much longer and have very much less intimate union—those from opposing faces appear to lightly interdigitate only towards their extremities. Besides the support they provide by this interlocking, slight and scarcely adequate though it appear, these cilia function as the actual strainers of the food particles, and this may be considered their particular duty.

That of the lashing cilia of the corner cells is well known—it is to create and maintain the incurrent water-stream.

Finally, coming to the short cilia (*F.c.*) that clothe the whole frontal (ventral) face of each filament, observation upon the living animal leads me to believe that the special function here is the propulsion of food particles outwards to the branchial crest, where, as in the pearl oyster, I have been able to recognise a ciliated pathway leading directly to the base of the labial palps.

Thus when a diatom or an algal spore is intercepted by the sieve formed by the interdigitation of the long cilia of the lateral bands it is thrown out upon the broad frontal path of short cilia which pick it up and propel it swiftly to the gill crest, where the cilia of the crest pathway catch it and propel it at right angles to its first course onwards to the anterior apex of the gills, where it is surrendered to the care of the palps.

THE VASCULAR SYSTEM.

The vascular system of *Placuna*, in common with that of more typical Lamellibranchs, consists of a central organ of propulsion, the heart, of arteries having a definite lining of epithelial cells, of irregular ill-defined spaces or lacunæ, and of a well-developed series of more or less well-defined and regularly disposed permanent channels or sinuses, functioning in the main as venous trunks, but differing therefrom histologically, as the walls of these sinuses are without an epithelial lining. The blood is colourless.

It is characteristic of the Anomiidæ that the heart is not contained in a pericardium, and this peculiarity is well seen in *Placuna*. Here the thick-walled ventricle (*V.*) lies suspended freely in the mid-posterior region of the pallial cavity, just above the posterior ventral angle of the visceral mass; its relative position is dorsal to

the rectum, and in aspect its apex is turned slightly towards the left side (*V.* Plate II., fig. 4).

Its attachment to the visceral mass is by a narrow strip of tissue extending upwards from the closely approximated entrances of the auricles to the emergence of the aorta (*Ao.*). The ventricle is, therefore, not traversed by the rectum, nor even closely approximated thereto; indeed no intimate relation exists between them.

In shape the ventricle is roughly of sub-globular form, with the apex pointing posteriorly and slightly to the left Its greatest length in the largest of the preserved adults examined was not more than five millimetres, the greatest breadth four mm. The walls are muscular and extremely spongy, allowing thereby of great distension; the cavity is crossed by numerous muscular trabecula (Plate V., fig. 28).

Two tubular auricles, one from each side (*Au.r.* and *Au.l.*, figs. 16 and 17), enter the ventricle at the ventral end of its attachment to the visceral mass; the auriculo-ventricular apertures (*V.a.v.*) are placed close to one another, but each is quite separate. Each is guarded by a clearly-defined mitral valve, consisting of two semi-lunar membranes effectually preventing reflux of blood to the auricles. A single aorta, the anterior, is given off from the ventricle a little way dorsal to the auriculo-ventricular apertures, its opening provided with a single flap-shaped valve of simple structure (*V.ao.*).

The auricles are paired and tubular; they differ considerably in calibre—another instance of the far-reaching asymmetry of this mollusc, the left one being nearly double the diameter of that on the right. They approach the ventricle horizontally from the anterior aspect, and appear as two tubular arms embracing the base of the visceral mass. They lie on the right and left sides, just beneath the thin tissue of the mantle and midway between the dorsal aspect of the adductor muscle and the ventral portion of the liver. Anteriorly each is continuous with a large vessel carrying blood from the anterior apex of the ctenidium of its own side; indeed the auricles appear as the terminal dilated portions of these vessels, the common efferent branchial trunks (*C.br.eff.*). In this lack of specialisation the form of the auricles in *Placuna* is particularly noteworthy.

In common with the Pectinaceæ and Ostraceæ, the auricles themselves independently intercommunicate by a short transverse channel (*Au.ch.*, fig. 16), but *Placuna* is remarkable in that this connecting passage is particularly wide, and situated relatively so far distant from the ventricular end of the auricles as to be scarcely recognisable as an inter-auricular channel. This abnormal situation is obviously consequent upon the peculiarly elongated form assumed by the auricles. In one abnormal adult individual obtained from Tuticorin (S. India) only one auricle, the left, opened directly into the ventricle (Plate III., fig. 18). The right was connected in no way with the ventricle; it was continuous posteriorly with the rectal sinus, and anteriorly with the right efferent branchial trunk. The transverse auricular canal appeared very wide, so

through this all the blood brought by the right auricle passed into the left auricle, and thence into the ventricle by this indirect route. Probably this abnormality indicates a tendency towards the eventual suppression of the right auricle, and to a condition wherein the ventricle will have but a single auricle (the left) opening into it. We can now understand why *Placuna* has but one aorta (the anterior), whereas in most other Lamellibranchs there are both an anterior and a posterior aortic trunk with independent egress from the ventricle.

The single aorta (*Ao.*, Plate III., fig. 15) is given off from the ventricle close to the dorsal extremity of its attachment to the visceral mass. It divides almost immediately into two large trunks, (*a*) an anterior, running dorsally close to the posterior edge of the visceral mass, and (*b*) a posterior, having a course directed anteriorly and ventrally.

The anterior aortic trunk, the aorta proper, is markedly asymmetric in its position ; it runs superficially immediately beneath the left surface of the visceral mass and can be readily traced, together with the initial course of its main branches, by removal of the left mantle, when these vessels are seen mapped out clearly on the surface. The first two main branches given off by the aorta after the emergence of the great posterior trunk both run anteriorly and superficially within the visceral mass for a short distance and then turn inwards to supply the stomach, digestive gland and portions of the intestine and gonad (*Art.visc.* and *Art.hep.*, fig. 15). More dorsal still, a small artery, the posterior common pallial artery (*Art.c.p.*), leaves the aorta and, first running dorsally, curves round the ventral extremity of the posterior cardinal hinge tooth, and then, when midway towards the hinge, turns posteriorly and runs along the margin of a thin portion of reproductive tissue to the free dorsal edges of the mantle, where it divides into two long peripheral branches, the right posterior pallial arteries (*Art.pp.* and *pp.'*), which run respectively along the posterior edge of each mantle lobe.

Having given off the posterior common pallial artery, the aorta curves forwards and a little dorsally, and after sending a small vessel to supply the posterior half of the median dorsal hinge lobe at the level of the hinder cardinal hinge tooth and midway between it and the corresponding extremity of the anterior cardinal tooth, the aorta finally ends by bifurcation into a dorsally directed anterior common pallial artery (*Art.c.a.*) and a ventrally running palpar artery (*Art.pa.*). The former, after giving off a small artery to the anterior half of the median dorsal lobe, passes forwards to round the ventral extremity of the anterior cardinal tooth and then upwards and forwards to where the mantle lobes join anteriorly. Here the common artery bifurcates in similar manner to its fellow at the posterior end of the hinge, and so gives rise to two branches, the anterior pallial arteries (*Art.a.p.* and *Art.a.p.'*), which run marginally within the anterior edges of the respective pallial folds. In this way are formed two circumferential blood-vessels, one in each mantle, which run along the

two edges from a point dorsal and anterior where they receive blood from the anterior common pallial artery, to a point posteriorly where they receive blood from the posterior common pallial artery. In each case it follows that streams of arterial blood must meet each other within these pallial arteries, since they are fed from each extremity; however, as these pallial vessels give off numerous branches to the pallial and velar edges and are of minute calibre, and as their blood-feeders are both among the more distal of the branches given off from the aorta, the blood-pressure at that ventral point where the two streams meet must be so greatly reduced as to cause no opposition of blood currents to occur.

The common palpar artery curves forwards and somewhat ventrally towards the dorsal aspect of the palps, where it bifurcates to furnish a branch to each palp.

It is worthy of note that a special supply of arterial blood is furnished to the tissues in contact with the anterior and posterior thirds of the hinge line, by a series of minute but very distinct arteries branching off successively at short intervals from the terminal section of the anterior and the posterior common pallial artery respectively.

As already mentioned, the posterior branch of the aorta—what may be called the ventral artery (*Ao.v.*)—arises at a point very close to the ventricle. It runs in an anterior direction for a short distance, then turns ventrally, dipping between the two tubular auricles, to run along the anterior aspect of the adductor muscle between the kidneys, its calibre decreasing as it goes. Opposite the anterior corner of the base of the visceral mass it gives off a fairly stout branch (*Art.add.*), which enters the substance of the adductor and splits at once into a number of dendritic twigs. From this point, continuing its course along the surface of the muscle, there is next given off a long branch on the right side to the sac of the crystalline style, which thence runs back along the whole course of the sac, supplying branchlets thereto as it goes.

At the level of the great parieto-splanchnic ganglionic mass three short branches (fig. 15, *Art.add'.*) are given off successively from the ventral artery, which enter the adductor muscle and split up dendritically into numerous ramifying branches and twigs. Other small vessels are also derived from the extremity of the ventral artery; two of these pass posteriorly along the ventral surface of the muscle towards the rectum, and it is from each of these that a branch is given off to the pallial sense-organ.

Venous Sinuses.—Blood distributed to different parts of the body by the arteries passes eventually into small ill-defined lacunar spaces, and these run together into larger spaces, the sinuses, of greater definiteness and permanence. In *Placuna placenta* the course of the principal sinuses is more easily followed than in most Lamellibranchs; these vessels separate in the main into two series—the pallial and the viscero-pedal. The blood collected by the former, as well as that from the rectal sinus, passes directly to the auricles by way of the common efferent branchial trunks, while that from all the viscero-pedal sinuses, excepting the rectal, enters the

branchial circulation and passes to the gills for purification before being returned to the heart.

Pallial Sinuses.—Fig. 19 on Plate III. depicts graphically the arrangement and course of the principal pallial sinuses within the left mantle. The principal one is a great curved vessel, the anterior ventral pallial sinus (*Sn.pall.a.v.*), embracing within its concavity the adductor muscle. It runs almost midway between the adductor and the pallial edge, but rather closer to the former. The main branches feeding it appear all to arise on the distal side, so their function is the draining of the pallial tissues between the main sinus and the pallial edge. The sinus itself drains into the left common efferent branchial trunk almost at its origin—that is, close to the fleshy accessory excretory organ—but, just before doing so, receives a very large, well-branched sinus—the anterior dorsal pallial sinus.

A somewhat similarly disposed pair of sinuses (*Sn.pall.p.v.* and *Sn.pall.p.d.*) drain the posterior region of the left pallial lobe, but the two members are smaller, with fewer branches than the members of the anterior pair. They join just behind the level of the lower margin of the heart and run forwards at this level as the common posterior pallial sinus to empty into the left common efferent branchial trunk at the same place as the anterior pallial sinal opening. In the right mantle the anterior ventral pallial sinus is about as well developed as its counterpart on the left side; the dorsal member of the pair is weakly developed, and there appear to be no equivalents present of the posterior pallial pair. The suppression of these latter and the degeneration of the dorsal member of the anterior pair is correlated with the fact that the upper part of the right mantle, instead of being free, as is that on the left, is adherent to the surface of the visceral mass. As a consequence, the function of the suppressed pallial sinus is usurped by the visceral sinuses of the right side, which, it is noteworthy to remark, are extensively ramified and much more highly developed than those on the left side of the visceral mass. In this connection it may be remarked that, so far as the blood system is concerned, the left aspect is pre-eminently the arterial, the right is distinctly the venous.

Another point of great interest connected with the pallial sinuses is the association of black pigment with their trunks and main branches. The intensity of pigmentation varies considerably; sometimes the whole mantle is more or less deeply suffused externally, the sinuses showing up as darker lines on a dusky ground, the pigment being denser along their course; in other individuals pigment is restricted to the trunk vessels and their branches. The significance of this will be treated of elsewhere.

Visceral Venous System.—The principal vessels of this group may be enumerated as (*a*) the unpaired rectal sinus, (*b*) the paired main visceral sinuses, (*c*) the small median sinus, and the paired renal sinuses.

The first of these, the rectal sinus (*Sn.r.*, fig. 15), runs along that posterior portion of the kidney which overlies the rectum, and as they are closely associated, it

would appear that some elimination of waste products may here take place. This sinus receives some portion of venous blood from adjacent portions of the right mantle. It runs directly to the heart, uniting with the right auricle just under the right auriculo-ventricular aperture in such manner that it appears as if it were a backward prolongation of this auricle, just as the right common efferent branchial trunk appears as a forward prolongation.

Within the main visceral mass the two principal sinuses consist of an asymmetric pair, disposed vertically close behind the junction of the palps with the body. The right (*Sn.v.r.*) is the larger and has many branches, which in turn frequently sub-divide. These branches drain blood from the greater portion of the visceral mass, including the whole of the median and right sections of the main mass; a branch from the posterior visceral lobe also empties into the main or vertical sinal trunk.

The left main visceral sinus (*Sn.v.l.*) lies parallel to the right one, and receives branches from the anterior portion of the right side of the visceral mass and also a strong branch from the foot.

A very little above the level of the lower margin of the palps the left visceral sinus turns inwards and joins its fellow on the right, forming a short median sinus (*Sn.m.*). This almost immediately divides into two large, well-defined trunks, the renal sinuses, passing ventrally to the paired limbs of the kidney. Here the blood stream bathes the renal tubules with consequent elimination of waste products. From the ventral extremity of each limb of the kidney and close to the parieto-splanchnic ganglion, a common afferent branchial trunk (*C.br.aff.*) conveys this partially-purified blood into the branchial mesentery of its own side. The course of this afferent vessel curves at first outwards (anteriorly and slightly ventrally), always within the mesentery, till it reaches rather less than half-way to the proximal margin or base of the gills. Here it divides into a short anterior and a long posterior branch. From both branches a multitude of fine vessels carry blood from the afferent trunk into a most extensive and intricate vascular network (*Br.ms.pl.*, figs. 4 and 15), occupying the whole distal section of the mesentery and from which eventually pass the tubules supplying the branchial filaments.

The remainder of the branchial circulation is practically the same as in *Anomia* and is described in the pages treating of the structure of the branchiæ. It will suffice to say here that, after oxidisation in the mesenteries and the gill filaments, the blood from the gills is returned to the heart by two common efferent branchial vessels, each of which, as already noted, runs directly between the anterior apex of each gill and the auricle of the same side—appearing, indeed, as a forward prolongation of the auricle.

Course of the Circulation.—We are now in a position to outline the course of the blood circulation through the body. In the first place, we see that the blood reaching the ventricle through the two auricles consists in part only of fully-purified blood from the gills and kidneys, a portion of more or less impure blood arriving in the auricles

direct from the mantle lobes[1] and hinder portion of the body by way of the rectal and the anterior pallial sinuses.

From the ventricle this mixture of pure and impure blood is pumped into all parts of the visceral mass, muscles, and mantle. Thence it passes into irregular lacunar spaces, from which the sinuses collect it. That collected by the pallial and rectal sinuses goes, as already described, directly back to the heart, while that gathered into the visceral sinal vessels is carried to the kidneys and the gills, whence, after purification, it passes by the common efferent branchial trunks into the auricles.

Reviewing the circulatory system of *Placuna* as a whole, several most noticeable features become apparent. The more striking are, (*a*) the primitive tubular character of the auricles in contrast with the specialised and centralised condition seen in the more highly-developed pearl oyster, where the ventricle and auricles form a closely associated or single mass; (*b*) the marked asymmetry of the auricles and their inter-communication by way of a *particularly* wide channnel relatively remote from the ventricle; (*c*) the presence of a single aorta, the anterior, consequent upon the suppression of the posterior, whereof the place is taken by a large branch given off by the anterior aorta immediately after it leaves the ventricle; following on this suppression of the posterior aorta, we see that both the anterior and the posterior pair of pallial arteries arise from the dorsal branches of the anterior aorta—in the pearl oyster the anterior and the posterior aorta supply respectively one pair of these pallial vessels; (*d*) lastly, the absence of a pericardium surrounding the heart is particularly striking, a condition of affairs confined among Lamellibranchs solely to the Anomiideæ; this results in the ventricle lying free and uncovered within the mantle cavity. Comparing with *Anomia*, we note in that genus that there are the vestiges of a cœlomic space in certain tiny glands or funnels opening into the two kidneys, according to Sassi. In *Placuna* these laterally-placed "funnels" appear to be paralleled by a conspicuous fleshy glandular body (accessory excretory organ) on each side, opening respectively into the right and left nephridia.

Tendency towards further modification in organisation suggested.—From the greater development of the left auricle considered in conjunction with the exceptional width of the inter-auricular channel, it seems to me that there exists in *Placuna* a well-marked tendency towards the eventual modification of the right auricle in such manner that, instead of carrying the blood it receives to the ventricle, it will cease at last to be connected organically therewith and instead will pour its blood stream wholly into the left auricle by way of the further widened inter-auricular channel. This theoretical deduction of the probable results is depicted in fig. 18, which, however, is not an imaginary diagram, but an outline sketch of a similar *actual*, though

[1] This blood is probably oxygenated to some extent even though it does not pass through the gills, as the pallial membranes are so tenuous as to be capable of allowing some exchange of gases between the water without and the blood which flows within. In this way the wide expanse of free pallium in *Placuna* may be considered in the nature of an accessory branchial organ.

abnormal, arrangement of vessels noted in an individual obtained in 1907 from a muddy inlet near the town of Tuticorin in South India. Here we see the rectal sinus opening directly into a vessel, which, without doubt, is morphologically the right auricle, but in this case with no connection whatever with the ventricle, intercommunicating instead by a wide channel, the inter-auricular passage, with the left auricle, and connected anteriorly with the right common efferent branchial trunk, wherefrom it receives blood in the usual manner of a right auricle. In this individual the ventricle has but two openings, that from the left auricle and that from the aorta.

EXCRETORY SYSTEM.

The excretory system is considerably removed from the normal Lamellibranch type, a result of the absence of a pericardium and of the marked asymmetry of the animal generally.

It consists of two paired asymmetric nephridia, connected dorsally by an extremely short and wide transverse channel, the inter-nephridial passage. Two distinct regions are recognisable in each nephridium, an anterior section consisting of a laterally flattened tubular region, with much folded walls lying anterior to the inter-nephridial passage, and approximately of equal size in both nephridia, and of a cæcal continuation directed posteriorly, of great length in the case of the right nephridium, short, and little more than rudimentary in that of the left (figs. 6, 7, and 8).

The general form and course may be readily understood if we represent the organ diagrammatically as an H-shaped tubular organ with the posterior part of the left leg much shorter than its fellow on the right, thus—H. It lies curved in crescent form round the greater part of the adductor muscle, the anterior symmetric horns or branches curving downwards over the anterior face of this muscle, while the posterior horn on the right, representing the cæcal prolongation of the right nephridium, lies upon the upper surface and along the greater part of the rectum. The cæcum of the left nephridium appears as the abbreviated horn on the left.

The two anterior branches of the conjoined nephridia (*Neph.r.* and *Neph.l.*), usually of a dark brown colour, as are also the other sections, run parallel with each other along each edge of the antero-dorsal curvature of the adductor muscle, and thence downwards along its anterior face, terminating about the level of the parieto-splanchnic ganglionic mass (fig. 4). Dorsally the two tubes communicate widely with their posterior cæcal prolongations.

The right branch in the anterior or symmetric region of the kidney is rather broader than the left, and is more deeply lobed ventrally; viewed superficially it has the appearance of being partly sunk in the tissues of the right mantle. It is not so in reality. Its posterior face is intimately associated with the proximal portion of the pyloric cæcum to which it is bound by a thin sheet of connective tissue. From its

anterior face the first section of the right branchial mesentery is hung, and in like manner the fore part of the left branchial mesentery is suspended from the face of the left renal tube.

The extremely short internephridial passage lies transverse to the median plane, bounded dorsally by the visceral mass, ventrally by the adductor muscle, and anteriorly by that ventrally-directed lobe of the visceral mass which pushes its way downwards and forwards between the auricles and apparently through the nephridia in its accompaniment of the pyloric cæcal sac. Hence in serial sections we see the internephridial passage (fig. 24, *I.n.p.*) as a wide transverse channel connecting the two nephridia immediately behind an "island" of reproductive tissue having a cross section of the pyloric cæcum in the centre, and one of the ventral trunk of the aorta to the left side.

Posteriorly each nephridium is prolonged in a posterior ventral direction as a cæcal prolongation; that on the left very short, that on the right relatively of great length. The latter runs for some little distance on the right side of the rectum, and then twists over so as to run in a truly median plane along the posterior face of the rectum almost as far as the anus.

Along most of its course the right renal cæcum is accompanied by the rectal sinus so that the blood thus carried to the heart has some part of its waste matter removed at this stage of its cycle.

Each nephridium has a single opening (*Rn.o.*) to the exterior; it lies at the ventral extremity of each renal tube, and opens into the mantle cavity at the end of a short narrow duct situated close to the parieto-splanchnic ganglion. To ensure more effectively the rapid removal of the renal excretion poured forth by these ducts, each aperture opens into a long open channel or gutter running close to the edge of the adductor. That on the right side is particularly well developed; at first it is narrow and deep, but as it proceeds posteriorly it gradually widens and loses depth until at last it dies away towards the hinder ventral angle of the adductor, the excretion it conducts away being then well under the control of the excurrent outflow from the gills.

Of the two sections, the anterior region is the most glandular: there the walls are deeply folded and pouched on a somewhat complicated plan (figs. 29 and 30, *Neph.r.*). The walls of the internephridial passage and of the posterior cæcal region are also fairly extensively folded and puckered to increase the secreting area (fig. 28, *I.n.p.*).

The cells lining the walls of all sections of the nephridia are uniform in appearance and size (fig. 27). They consist usually of a single layer of large irregularly cubical secreting cells, very clear and much vacuolated. The cell wall is very distinct, and the nuclei, of large size, are situated towards the bases of the cells. In some places the cells are somewhat crowded, and occasionally may be two and even three deep.

The gonad opens in the roof of the internephridial passage by a single small duct (fig. 6, *Go.a.*), once more emphasizing the asymmetry of this mollusc.

Two other small ducts also open into the nephridia, one on each side from a compact reddish-brown fleshy gland situated on each of the common efferent branchial trunks immediately between the ventral margin of the palps and the anterior ventral corner of the visceral mass. These two glands (figs. 4, 6-8, *Acc.ex.o.*) are sub-triangular in lateral view, and measure about three millimetres along each side. They are made up of closely-packed tubules lined with large cells which leave but a small lumen (fig. 29, *Acc.ex.o.*); compact though they are, there is little doubt that we have here a highly-specialised form of Keber's organ, or so-called pericardial glands.

It has been noted that no pericardium appears to be present in *Placuna*. The same statement was formerly made of *Anomia*, but although Pelseneer argued that the vestige of a pericardium does persist in a much reduced and vestigial form as an obscure connection between the hinder portions of the nephridia, which in *Anomia* lie on either side of the rectum, Sassi (*loc. cit.*) controverts this, and denies the existence of any vestige of a pericardium.

In *Placuna* I venture to suggest that the two fleshy glands which open right and left into the most dorsal part of the right and left nephridia respectively represent the reno-pericardial tubes of Lamellibranchs more normal in the structure of this organ, for example, *Margaritifera vulgaris*, where each of these tubes is seen as a wide sleeve proceeding from the pericardium on each side to insertion in the wall of each lateral nephridial chamber. In this type the ventral surface of the pericardium is beset with excretory glands—a Keber's organ. In *Placuna* it would seem as if these glands had shifted outwards to the distal extremities of the reno-pericardial ducts and there massed compactly, a change accompanied, if not indeed produced, by the gradual obliteration of the central or true pericardial chamber. If this hypothesis be correct, then the dark compact glandular bodies, seen one on each lateral wall of the renal organ, represent all that is left in *Placuna* of the pericardium and reno-pericardial tubes.

NERVOUS SYSTEM.

The central nervous system of *Placuna*, although it consists of the same components as in other Lamellibranchs, suffers extreme secondary modification due to torsion, fusion, and suppression of parts consequent upon the asymmetry of the other organs and their general concentration and excessive development upon the right side of the body.

It is constituted of the usual three ganglionic centres, (*a*) the cerebral, consisting of two separate paired ganglia widely separated and asymmetric (figs. 10 and 11, *Cer.g.*); (*b*) an apparently single pedal ganglionic mass (*Ped.g.*) formed by the fusion of originally paired pedal ganglia, which are still resolvable as such on minute examination; and (*c*) a single median parieto-splanchnic ganglion (*Par.sp.g.*), showing little trace of ever having been paired except in the paired nature of the nerves it gives off.

The connectives follow the normal arrangement and number; a pair of long and stout cerebro-visceral connectives (*C.v.con.*) join the cerebral and parieto-splanchnic ganglia, while a very short pair of similar cords (*C.p.con.*) link the cerebral and pedal centres.

In the living condition the ganglia and the stouter portions of the principal nerves are bright orange yellow in colour, and since the ganglia are situated superficially this enables them to be found with comparative ease.

The cerebral ganglia.—If the labial palps be folded back from the middle line, the right ganglion (fig. 23, *Cer.g.r.*) may readily be seen lying superficially as a large and conspicuous pale orange-coloured mass close to the united bases of the right pair of palps, at a point about midway between the mouth and the base of the foot. The left ganglion lies at about the same horizon, at the bases of the left palps (*Cer.g.l.*); it is distinctly smaller than the right, and as it does not lie so close to the surface it is somewhat difficult to locate. A long U-shaped nerve cord, the cerebral commissure (figs. 10, 11 and 13, *Cer.com.*), passing dorsally over the anterior end of the œsophagus, unites the right and left ganglia; in consequence of the considerable distance from the œsophagus at which the latter are situated, this cord is unusually long.

Ventrally, each ganglion gives off two other connectives, one short and delicate, the cerebro-pedal connective (*C.p.con.*), to the pedal ganglion, the other very long and stout, the cerebro-visceral (*C.v.con.*), to the parieto-splanchnic ganglionic mass.

Each cerebro-visceral connective runs in a ventral direction along the base of the palps of its own side to the anterior extremity of the gills, where it leaves the visceral mass and passes, still pursuing a ventral course, to between the anterior surface of the adductor and the posterior of one of the renal tubes. Its further course follows that of the renal tube of its respective side along which it runs on the postero-lateral aspect to junction with the dorsal margin of the parieto-splanchnic ganglion.

In addition to the supra-œsophageal commissure and the connectives to the pedal and parieto-splanchnic ganglia, each cerebral ganglion gives off anteriorly a common anterior pallial nerve (*N.a.p.*), which passes into the mantle at its antero-dorsal corner.

Other small nerves also arise from the cerebral ganglia to innervate the pallial palps and adjacent tissues.

Pedal Ganglion.—The two primitive components of this nerve centre are so closely approximated that they cannot be clearly resolved except by microscopic examination of serial sections. The dual nature is then readily made out and it is seen that the lateral mass which represents the original right ganglion is much the larger of the two; no trace of commissure persists. The ganglion is situated medianly, on the dorsal side of the base of the foot. In addition to the cerebro-pedal connectives given off at its upper and external corners, a stout pedal nerve arises from this ganglion and passes directly into the foot, where it can be traced to the tip, giving off small twigs along its course.

The parieto-splanchnic ganglion is the largest of the ganglionic centres and attains relatively enormous proportions. It is not distinguishable into separate parts further than may be suggested by the two small anterior lobes where the cerebro-visceral connectives enter. It rests in a slight depression on the anterior ventral curvature of the adductor close to the ventral extremities of the paired region of the nephridia.

In addition to the connectives to the cerebrals, two distributory trunks, the branchial nerves (*N.br.*), leave it anteriorly, while two other large nerves, the right and left posterior common pallial, emerge from its hinder border, and a second pair, the adductor nerves, pass from the posterior aspect direct into the tissues of the adductor muscle.

The two branchial nerves appear symmetric and of equal size. One leaves each anterior lateral corner of the ganglion, passes forwards, and at once enters the branchial mesentery; then, abruptly and at an acute angle, it curves posteriorly, to run the remainder of its course approximately parallel with the ctenidial base. At first the branchial nerve runs at some distance from this axis, but gradually draws nearer as it approaches the posterior extremity of the gills, where it terminates. Each nerve gives off numerous branches in its course.

The adductor nerves, as mentioned, arise right and left from the posterior surface of the ganglion. Their sole function is to innervate the adductor muscle; in saggital serial sections through young individuals their dentritic branching is beautifully shown (fig. 29).

The remaining nerve trunks, the great pair given off from the posterior border, each breaks up immediately on leaving the ganglion into an inner or internal nerve and several lateral ones. The first two of the latter, the pallial nerves (*N.pall.*), radiate outwards to innervate portions of the mantle and, with the nerves from the anterior common pallial trunks given off from the cerebral ganglia, form that complex network of nerves within the mantle lobes known as the pallial plexus, while the third passes posteriorly without turning outwards till, when close to the distal end of the pyloric cæcum, it bends ventrally, to pass direct to the elongated tumid pallial sense organ wherein it bifurcates.

The inner nerves (*N.v.v.*) pass posteriorly within the sheath of the adductor muscle in the direction of the anus. They appear to innervate the tissues and organs of the ventral rectal region.

The only *sense organs* present are of an extremely low type, showing a minimum of specialisation. Neither otocyst nor osphradia appear to be present. A pair of the pallial or abdominal organs of Thiele are, however, present. With this exception, all we have is the development of sensory epithelial cells singly and in small groups upon the papillate processes of the mantle edge. In general they have the structure and arrangement of those seen upon the pallial edge of the pearl oyster. The general

surface of the mantle and the palps is also sensitive, but not to greater degree than is usual among other Lamellibranchs.

Each of the pallial sense-organs (figs. 10, 11 and 13, *S.o.*) is an elongated tumid body situated on the inner surface of each mantle close to the distal end of the pyloric cæcum. Innervation is by a strong branch of the posterior common pallial nerve, which splits up into two principal branches immediately upon entering. The surface of the swelling is covered with epithelium containing specialised sense-cells. The size of these bodies is very much greater than in *Margaritifera vulgaris*, implying a function of considerable importance.

THE REPRODUCTIVE ORGANS.

Placuna placenta is dicœcious and the sex of each individual remains the same from season to season throughout life; no form of hermaphroditism occurs.

In each sex the gonad or reproductive organ appears to the naked eye as an irregular mass of yellowish tissue largely enveloping the stomach, liver, and intestine, and pushing out irregular tumid lobes into various parts of the right mantle. No sign is given that the gonad is paired. Even in very young specimens there is absolutely no evidence in favour of such view, whereas the presence of a single genital opening and the great asymmetry of the organ point to the suppression of the left member of the original pair. The one remaining is purely and simply an irregular ramified mass closely associated with the course of the alimentary canal. It is distinguishable as a central mass and a definite number of large lobes; the first, as before stated, envelopes and hides the greater portion of the stomach, liver and visceral coil of the intestine, constituting the greater part of the outer tissue of the main visceral mass. The lobulated masses which burrow in various directions into the right mantle consist of two thin extensions into the dorsal or hinge lobes of the mantle, one anterior and the other posterior to the central lobe bounded by the cardinal teeth; one long, narrow, greatly curved lobe following the entire course of the pyloric cæcum (fig. 13), first downwards along the anterior face of the adductor and then turning posteriorly along its ventral aspect to a blind termination not far from the posterior end of the gills; another tumid and somewhat irregular mass envelopes the rectum, with it forming the rectal lobe of the visceral mass; the last of the large sections of the gonad lies immediately posterior to the visceral mass (*Go.p.*, figs. 4 and 13).

The last two lobes in conjunction with the posterior face of the visceral mass bound the triangular cardiac chamber, except on the lateral aspects; at the dorsal and posterior angles these three masses are united and placed in communication with each other by short and very narrow bridges of reproductive tissue; the intercom-

munication of these large lobes of the gonad is a very noticeable feature in *Placuna*.

Except the unimportant dorsal or hinge lobes which belong strictly to the main mass of the gonad enveloping the stomach and liver and are median in position, all the above-mentioned branch masses lie within the right mantle. The only portion that penetrates the left mantle is a small branch from the pyloric cæcal lobe which crosses from the right side at the attachment of the ventral end of the kidneys to expand into a disc-shaped mass covering and surrounding the proximal ends of the pallial muscles of this region.

The gonad in the male appears usually to be rather smaller than in the female. The sexes may be distinguished by the colour of the gonad; in the ripe female it is normally of an orange yellow tint, in the male it is duller and has more of a soiled yellow hue.

The gonad opens into the internephridial passage by a small aperture (*Go.a.*, fig. 6) situated in the roof of the passage. The aperture is therefore anterior to the ventricle, and midway between the auricles. From the position of the single genital aperture being in the roof of the internephridial passage, the reproductive products, when emitted into the renal organ, will pass readily in part to the right and in part to the left, and so be conducted into the respective ventral limbs of the nephridium, whence emission to the exterior will take place through the renal apertures situated on either side of the parieto-splanchnic ganglion.

Microscopical examination shows that intermingled throughout the whole gonad in both males and females is a very peculiar soft spongy tissue of obscure significance. Its nature is absolutely distinct from that of the reproductive tissue proper; in appearance it simulates a delicate and loose network of connective tissue. In young specimens the proportion of this enigmatical tissue is very large and it would appear to perform some distinct function other than that of a mere stromal framework—possibly it functions as a food reserve (see p. 91 for further remarks on the significance of this tissue).

Histologically each gonad is made up of a mixture of the spongy tissue above mentioned with great numbers of ramifying tubules on which cluster, grape-like, dense masses of saccate alveoli lined with germinal epithelium. The ultimate structure of the alveoli is best seen in a female. Here they are distinguishable as wide cæca containing ova in various stages of development, from a tiny cell arising by proliferation from the germinal epithelium lining the cæcum to ova free and fully formed ready to pass away.

Each ripe ovum when not deformed by reason of mutual pressure when the tubules are becoming swollen with undischarged ova is of a laterally compressed ovate outline (figs. 35 and 36), the narrow or stalked end having formed the place of attachment to the alveolar wall. Because of this last fact, the narrow neck of this

stalk eventually functions as a micropyle. The vitelline membrane enclosing the granular vitellus is slightly vacuolated; the nucleus is large and very granular and often contains two distinct nucleoli.

The spermatozoa arise by a similar proliferation of the germinal epithelium in the males; in maturing individuals the simple nature of each of the alveoli is masked by the presence of large quantities of unripe spermatozoa which obscure and practically obliterate the lumen. The individual spermatozoa are very minute and of the typical form seen in Lamellibranchs, each having a pear-shaped head, clear and highly refractile, with a long, delicate flagellum proceeding from the broader end.

The spawning season of *Placuna* appears to coincide with the onset of the north-east monsoon both in Ceylon and the Gulf of Kutch, the two localities where I have had opportunities to examine large numbers of individuals of various sizes. Thus in January, 1906, I found oysters of 1·5 centimetres diameter about three months old in Rann Bay on the Okhamandal coast, while the young seen in Tampalakam Bay, Ceylon, in May, 1905, being 4 cms. in diameter, were approximately six to seven months old—ages which give the spawning season as the month of October in the preceding year.

On *a priori* grounds this is what might be expected. The month of October witnesses a great change in weather on the Indian coast, with a concurrent variation in the specific gravity of the water on the *Placuna* banks. In Ceylon this is specially emphatic. October is pre-eminently a rainy month in the Tampalakam district; the influx of fresh water into the bay which results lowers the specific gravity and supplies the needed stimulus required by the window-pane oysters to bring on widespread emission of the genital products.

THE SIGNIFICANCE OF THE ASYMMETRY AND OTHER MAJOR PECULIARITIES OF *PLACUNA PLACENTA*.

The most striking and outstanding features which characterise the organisation of *Placuna* are the marked asymmetry affecting almost every organ, and the archaic characters retained by many of them.

Regarding asymmetry, F. J. H. Lacaze-Duthiers, working a half century ago on the anatomy of *Anomia ephippium*, belonging to a closely related genus, "was struck at the outset of the investigation with the importance and preponderance which the right mantle assumed over the left." A similar remark would apply with equal force to *Placuna placenta*.

In this species asymmetry affects practically the whole organisation. It is carried so far in the case of the reproductive system that this may be said to lie almost wholly within the right mantle.

The auricles are markedly asymmetric in calibre; the sinuses of the two mantle

lobes differ greatly in arrangement, whilst the posterior or rectal sinus is now unpaired; the posterior aorta has been suppressed; the hinder extension of the right kidney has developed at the expense of its neighbour on the left; the palps are asymmetric and the mouth and labia awry; the alimentary canal tends towards the right side, whilst the crystalline style, after its emergence from the visceral mass, lies embedded for the rest of its course within the right mantle lobe. The right member of both the retractor and the levator pair of muscles of the foot has disappeared and the nerve ganglia, as may be expected, share, though in modified degree, in the general asymmetry of the animal.

The meaning of this asymmetry is explicable if we consider the peculiar mode of life and habitat adopted by *Placuna*.

In Lamellibranchs possessing a byssus, by which they are enabled to affix to stones and rocks, and in siphonate forms which burrow in sand or mud, the body is maintained normally in a more or less vertical position. In *Placuna*, where both byssus and siphons are absent, the animal lies prone on the convex left valve upon the muddy bottom of those shallow waters of the Indies which it chooses as its habitat. It thus lies with the body in a horizontal position, with its organs more or less suspended from the flat right valve which is uppermost. In the same way its ally, *Anomia*, assumes a more or less horizontal position in life, as in it the byssus, which here protrudes in a calcified form from the right valve, anchors the animal permanently on its right side to some solid object, rock, stone, or another shell.

Now, in those forms of Lamellibranchs where the axis of the body is regularly maintained throughout life either approximately vertical in burrowing forms (*Cardium, Mya, Solen*), or at right angles to the plane of attachment in the case of fixed forms, as in *Arca* and *Mytilus*, the primitive bilateral symmetry is maintained, whereas in *Anomia* and *Placuna*, which maintain a horizontal axis in their habitat, asymmetry reaches a maximum. Intermediate forms of Lamellibranchs, with the axis of the body maintained habitually in some position between these extremes, reveal an asymmetry usually proportionate to the extent of the inclination of the axis of the body from the vertical. Thus, in the pearl oyster (*Margaritifera vulgaris*), where the inclination from the vertical is but slight, asymmetry is correspondingly small, and may be said to be limited to the valves of the shell. In these latter forms the conditions which produce asymmetry are mechanical, and are in the nature of stresses comparable with those which account mechanically for the asymmetry of typical gastropod structure.

But mechanical stresses will not account for the asymmetry of organs as seen in *Placuna*, otherwise instead of the organs tending to gravitate to the right or upper side of the body as the animal rests on the bottom, they would tend by gravitation to embed themselves in the lower or left mantle. The cause is rather to be sought in the obvious advantage of keeping the organs raised as far as possible above or beyond the

harmful influence of the mud whereon the shell rests. The reason for the animal lying on its convex side is unmistakeably the same. As mud-laden water enters the shell to pass to the gills, the heavier particles tend to settle and deposit, and it becomes a manifest advantage to have the organs on the aspect above where this settling takes place. The scallops (*Pecten maximus* especially) and the edible oyster (*Ostrea*) supply analogies of the advantage to unattached animals, whose life axis is horizontal, to have one of their valves convex upon which they may lie. *Pecten* rests thus, while in the case of the oyster (*Ostrea*), which in the natural condition, living attached to rocks, is attached by its left or convex valve, those that have been detached for cultural purposes are preferably laid down upon this convex valve, as this is found distinctly beneficial.

In all Lamellibranchs, with the exception of the Anomiidæ, the excretory system opens on the one hand to the exterior and on the other into a definite portion of the cœlom—the pericardium. In the Anomiideæ, typified by the genera *Anomia* and *Placuna*, the absence of a pericardium is characteristic, and renders them unique amongst Lamellibranchs.

It was only in 1903 that Sassi (*loc. cit.*) was able to show that minute vestiges of the cœlomic cavity do persist in *Anomia* in the form of tiny blind tubules communicating with each kidney, but without relationship to the heart. Sassi at the same time showed that the transverse tube, or internephridial passage connecting the kidneys, is not of cœlomic value, being lined with cells similar to the secretory cells in other parts of the renal organ.

In *Placuna* there is, as we have seen, a wide duct connecting the right with the left kidney. This is, undoubtedly, strictly homologous with the transverse renal passage found by Sassi in *Anomia;* in both the passage lies anterior to, and at the level of, the ventricle, and between the crystalline style sac and the rectum; in both, the cell structure of the wall is similar to that of the general renal surface. This last fact compels us to look elsewhere in *Placuna* for the vestige of a cœlomic cavity.

I have been able to find nothing similar to the two groups of blind ciliated funnels ("*Wimpertrichtern*") described by Sassi as representing minute vestiges of the cœlom, but I am strongly inclined to the belief that the pair of small triangular glandular organs, one of which is situated superficially on each side at the anterior ventral corner of the visceral mass, and which open into the most dorsal section of each kidney, are comparable to them and probably homologous. As in Sassi's funnels, in *Anomia* they lie in front of the passage connecting the kidneys; likewise they open directly into these organs.

In *Placuna* these glandular bodies are much larger, more compact, and more conspicuous than those in *Anomia*. They appear functionally to be of superior importance, and exhibit a suggestive resemblance to the dark-hued pericardial glands (Keber's organ) so frequently met with in other Lamellibranchs, as, for example, the

dark brownish glands upon the auricles of the pearl oyster. If my theory be correct then we have in *Placuna*, in these accessory excretory glands, the homologues of Sassi's ciliated funnels and the sole vestiges of the cœlomic cavity.

Were we to suppose, as is not unreasonable, that originally *Placuna* had a fairly normal pericardial cœlomic space, with a group of accessory (pericardial) glands on the inner surface of the pericardial wall towards the reno-pericardial apertures, then we have now a condition where the pericardial cavity has become obliterated with a concurrent development of the pericardial glands on each side of the body around what was originally the reno-pericardial aperture. The present extreme forward disposition of these glands, and consequent remoteness from the ventricle, is of no force against this view for two reasons, namely—(*a*) the auricles, which it is difficult to differentiate from the common efferent branchial trunks, reach as far forward as the glands in question—indeed the base of each gland is connected with the upper wall of the efferent branchial trunk, and (*b*) in several molluscs, as in *Margaritifera*, each reno-pericardial canal is so elongated forwards that its aperture is close to the anterior apex of the gills, a position similar to that of the glands present in *Placuna*. The aperture of each of these accessory excretory glands may be considered as the morphological equivalent of a reno-pericardial aperture of more normal types, and the glands themselves as the sole remnant of the cœlomic cavity.

Yet another extreme peculiarity seen in *Placuna* is the presence of a large quantity of delicate tissue intermingled with the tubules and ducts of the gonad. It appears to be too abundant to be regarded as constituting a stromal framework, but so far I am unable to determine definitely its significance. The one suggestion I have to make is that it possibly constitutes a food reserve, to be drawn upon when the condition of the water in which the individual lives is unfit for some reason to supply a sufficiency of food. For example, I believe that with many molluscs there are periods when, on account of excessive turbidity due to the suspension of great quantities of mud particles, feeding becomes so difficult and unsatisfying that this function is temporarily suspended, either wholly or in part. In the case of pearl oysters (*M. vulgaris*) in aquaria I have noticed a cessation of feeding to occur whenever on occasions the water supply (which passed to the aquaria without filtration) became charged with an excessive amount of fine sediment. In such cases, although the particles would be collected upon the gills and conveyed to the palps, these organs, after carefully forming them into pellets, invariably rejected them as unfit, presumably, for food purposes. *Placuna* lives under conditions where every flood carries quantities of fine sediment into its favoured backwaters, and where, too, tidal influences and wind-lop are often sufficiently strong to disturb the light sediment resting on the bottom of the shallows. Under such circumstances it would appear to be of distinct advantage to an animal to have a food reserve which would permit of temporary cessation from feeding when the condition of the medium in which it lives

is unfavourable for obtaining food without an undue admixture of unsuitable particles.

Backwaters, more or less brackish, are notable for a profusion of diatomaceæ; these organisms form the bulk of the food of *Placuna*, and to this fact we may correlate the extraordinary development of the crystalline style in this mollusc. Much enveloping gelatinous matter is needed to surround the sharp ends of the silicious frustrules and so prevent injury to the delicate walls of the intestine, and such supply is afforded by the continual wearing down of the end of the style where it projects into the stomach.

In its evolution *Placuna*, while retaining many archaic characters, as in the primitive disposition of the heart and the simple structure of the branchial filaments, has shown great plasticity in other directions, with the result that it is now one of the most interesting of Lamellibranchs in its peculiarities of general asymmetry and the extreme specialisation of certain organs; its *ensemble* is now such as adapts it most perfectly to the habitat it has chosen—an adaptation to environment second only to that most wonderful of mud-dwellers, *Lingula*, where the same end has been attained by an absolutely different path. In the one case life in an environment of the softest mud has been rendered possible by the adoption of the same principle as is embodied in the use of snow-shoes; here the animal *rests upon* the mud. In the other instance a muscular stalk of great length has been developed to enable the animal to project the edge of its valves above the mud, and yet have an anchorage to some shell or stone far down in the deeper and stiffer layers of the mud. At Balapur Bay, in Beyt Island, I have seen these animals living together in great abundance. Such mud-flats may, therefore, be characterised as distinguished by a *Lingula-Placuna* formation.

EXPLANATION OF PLATES.

INDEX TO REFERENCE LETTERS.

A.ch, afferent blood channel of gill filament.
A.l.c, antero-lateral cilia of gill filament.
Acc.ex.o, accessory excretory organ.
Add, adductor muscle.
Add′, anterior region of adductor muscle.
Add″, posterior ,, ,, ,, ,,
Anf, anal funnel.
Ao, aorta.
Ao.v, ventral trunk of aorta.
Au.ch, interauricular channel.
Au.l, left auricle.
Au.r, right auricle.
Art.add, dorsal arteries of adductor muscle.
Art.add′, ventral arteries of ,, ,,
Art.a.p, right anterior pallial artery.
Art.a.p′, left ,, ,, ,,
Art.c.a, anterior common pallial artery.
Art.c.p, posterior ,, ,, ,,
Art.hep, hepatic artery.
Art.pa, palpar artery.
Art.p.p, right posterior pallial artery.
Art.p.p′, left ,, ,, ,,
Art.visc, visceral artery.
Br, branchia.
Br.acc, accessory fold of the reflected outer branchial lamella.
Br.eff, efferent branchial vessel.
Br.l, left branchia.
Br.ms, branchial mesentery.
Br.ms.pl, plexus of blood capillaries in branchial mesentery.
Br.r, right branchia.
Br.ret, branchial muscle band.
C.br.aff, common afferent branchial vessel.
C.br.aff′, left common afferent branchial vessel.
C.br.aff″, right ,, ,, ,, ,, ,,
C.br.eff, common efferent branchial vessel.
C.p.con, cerebro-pedal connective.
C.st, crystalline style.
C.st.c, ,, ,, cæcum.
C.t, cardinal teeth.
C.v.con, cerebro-visceral connective.
Cer.com, cerebral commissure.
Cer.g, cerebral ganglion.
Cer.g.l, left cerebral ganglion.
Cer.g.r, right ,, ,,
D.gl, digestive gland.
D.gl.d, ,, ,, ducts.
E.ch, efferent blood channel of gill filament.
E.ep, epithelium of outer pallial surface.
F, foot.
F.c, frontal cilia on outer face of a gill filament.
Fl.tri, flèche tricuspide.
Go, gonad.
Go.a, external aperture of gonad.
Go.p, posterial genital lobe.
I.n.p, internephridial passage.
I.ep, epithelium of inner pallial surface.
Int, intestine.
Int. 1, first or ascending limb of intestine.
Int. 2, second or descending limb of intestine.
L.c, lateral cilia of a gill filament.
L.n.c, left nephridial cæcum.
Lev, pedal levator muscle.
Lev′, insertion surface of levator muscle.
M.ins.a, insertion surfaces of the anterior pallial muscles.
M.ins.p, the principal insertion of the posterior pallial muscles.
Mg.p, pallial margin.
Mg.v, velar margin.
N, nerve.

N.add, adductor nerve.
N.a.p, anterior pallial nerve trunk.
N.br, branchial nerve.
N.pall, pallial nerves.
N.s.o, nerve to pallial sense organ.
N.v, visceral nerves.
N.v.v, ventral visceral nerves.
Neph.l, left nephridium.
Neph.r, right nephridium.
O, mouth.
Oe, œsophagus.
Pa, palps.
Pall, pallium or mantle.
Pall.l, left pallial lobe.
Pall.r, right „ „
Par.sp.g, parieto-splanchnic ganglion.
Ped.g, pedal ganglion.
Periost, periostracum.
R, rectum.
R.n.c, right nephridial cæcum.
Ret, retractor muscle of foot.
Rn.o, renal orifice.
S.o, pallial sense organ.
Sep, transverse septum of gill filament.
Sk.b, skeletal band within a gill filament.
Sn, blood sinus.
Sn.m, median sinus.
Sn.p, pedal sinus.
Sn.p.o, opening of pallial sinuses into common efferent branchial vessels.
Sn.p.v, branches of posterior visceral sinus.
Sn.pall.a.v, anterior ventral pallial sinus.
Sn.r, rectal sinus.
Sn.rn, renal sinus.
Sn.v.l, left visceral sinus.
Sn.v.r, right „ „
St, stomach.
V, ventricle.
V.ao, aortic valve.
V.a.-v, auriculo-ventricular valves.
V.gt, gutter along ventral surface of rectal genital lobe.
V.v.l, ventral visceral lobe.
Vel, velum or velar margin.
X, left branchiae cut across, posterior half removed.
X', mantle cut away along this line.

PLATE I.

Fig. 1. Young window-pane oysters (*P. placenta*) of three ages, all seen from left side. The youngest is probably not more than six weeks old, the three oldest three to four months. Note that all the latter show well-marked "ears"; as many as three anterior ones are shown by the one on the left, bottom row. $\times \frac{3}{4}$.

„ 2. Two adult individuals, two to two and a half years old, seen from the right side, showing extensive injury caused by fish-bites, recent as well as of old standing. All injuries in process of reparation. Fig. B shows the remains of a posterior "ear" of considerable size; Fig. A shows a well-marked straight hinge line. $\times \frac{3}{3}$.

PLATE II.

Fig. 1. Inner aspect of the hinge region of the right valve of *Placuna placenta*; note the two long cardinal teeth of which the posterior is the longer, and the long row of short hinge teeth along the lower edge of the ligament (*l*).

Fig 2 and 3. Similar views from within of the hinge region of two left valves, showing the high variability of the hinge dentition. In these views the two long divergent black bands (*l.c.t*), represent the ligaments of the cardinal teeth belonging to the right valve. *l*, hinge ligament with dentated margin corresponding with the row of hinge teeth on the opposing valve. *a.e* and *p.e*, the anterior and posterior "ears" respectively of the shell.

Fig. 4. General anatomy of *Placuna* as actually displayed in a dissection; the animal is viewed from the left side, the left mantle lobe and the distal half of the left ctenidium being removed along the lines marked *X'* and *X*. Actual size of a two years old individual.

For explanation of the reference letters, see list above.

Fig. 5. Variations in the form of anal funnel in four individuals. ×5.

„ 6. Diagrammatic representation of the two nephridia in plan, showing the unequal development of the posterior cæca (*R.n.c* and *L.n.c*), the internephridial passage into which the genital duct opens (*Go.a*), and the relation of the ventral visceral lobe (*V.v.l*) which appears to pierce the nephridial sac. *Acc.ex.o*, accessory excretory organ; *Rn.o*, external renal apertures; *C.st*, crystalline style; *Ao.v*, ventral branch of aorta.

„ 7. Lateral view of the right nephridium.

„ 8. Lateral view of the left nephridium.
I.n.p, marks the situation of the internephridial passage.

„ 9. Insertion surface of the adductor muscle seen from left side. *Add'*, anterior region; *Add''*, posterior region.

„ 10. Plan of the nervous system, showing the ganglionic centres, connectives, and principal nerve trunks. For lettering consult the list on p. 93.

„ 11. Nervous system dissected out and seen from the left side. *S.o*, pallial sense organ; *Add*, adductor muscle: *O*, mouth; *Oe*, œsophagus. Other lettering as in Fig. 10.

„ 12. Diagrammatic transverse section across the two ctenidia to show the relative arrangement of lamellæ and vessels. *Br.ms*, branchial mesentery; *Br.aff.* and *Br. eff*, afferent and efferent branchial vessels respectively; *Br. acc*, accessory fold of the reflected outer lamella (*R.br.l*); *D.br.l*, inner and outer direct branchial lamellæ; *Ct.r* and *Ct.l*, right and left ctenidia; *Ct.j*, junction between inner reflected lamellæ of right and left ctenidia.

PLATE III.

„ 13. Dissection of *Placuna placenta* from the left side to show the course and situation of the digestive system, position of heart, and other details. The left mantle, the whole of the branchiæ, the left nephridium, the left palp and the superficial portion (left side) of the visceral mass have been removed. The foot is seen in moderate extension. *S.o*, right pallial sense organ; *Sn.pall.a.v*, anterior ventral pallial sinus of right mantle; *C.st*, crystalline style. Natural size of a two years old individual.

„ 14. Dissection of the alimentary canal, natural size.

„ 15. Outline sketch of a dissection of a two years old individual to show the course of the blood vessels. The vessels of the arterial system are shown by means of double lines, while the venous sinuses are shown in heavy black. The outline of the branchiæ is shown by means of a dotted line. Natural size. For explanation of lettering see list on p. 93.

„ 16. Diagram of heart seen from left side.

„ 17. „ „ „ „ „ right side.

„ 18. Diagram of an abnormal heart found in an individual from Tuticorin; in this case the right auricle does not communicate with the ventricle. Compare with Fig. 17 where the normal arrangement is depicted.
Lettering for these figures:—
V, ventricle; *Au.l*, left auricle; *Au.r*, right auricle; *Au.ch*, inter-auricular channel; *Ao*, aorta; *Ao.v*, ventral branch of same; *Sn.r*, renal sinus.

„ 19. Left pallial lobe viewed from without, to show the elaborate fan-like branching of the pallial muscles and their insertion centres (*M.ins.a* and *M.ins.p*), anterior and posterior to the adductor muscle (*Add*), also the course of the pallial blood sinuses (*Sn.pall*). These branched vessels are distinguished by means of double lines. *Lev'*, insertion surface of pedal levator muscle.

Part of the digestive gland and the superior branches of the aorta are indicated faintly through the thin non-muscular portion of the pallium adherent to the surface of the visceral mass. Nat. size.

Fig. 20. Semi-diagrammatic view of one of the minute spherical cestode larvæ found abundant in *P. placenta*, seen in optical section, showing how asexual multiplication occurs by the production of endogens. Only a single endogen (*End*) is here seen, but individuals frequently contain several; *C.c*, calcareous corpuscles.

„ 21. Advanced larva of *Distomun placunæ*, n.sp., a trematode frequently found encysted in this stage in Placunæ from the Gulf of Kutch.

PLATE IV.

„ 22. Vertical transverse section across the body of a three months old individual (preserved in formalin) about midway along the longitudinal axis. The section passes through the anterior section of the stomach and along the axis of the internephridial passage. It passes posterior to the parieto-splanchnic ganglion, and shows the relative position of the auricles (*Au.r* and *Au.l*) to the nephridia (*Neph.r* and *Neph.l*), the manner in which the intestine (*Int*) and the pyloric or crystalline style cæcum (*C.st.c*) leave the stomach and the relation of the distal region of the latter to the right mantle. × 16.

„ 23. Slightly oblique horizontal section of a similar individual at the level of the cerebral ganglia (*Cer.g.l* and *Cer.g.r*). Shows sections across stomach (*St*); last part of ascending region of intestine (*Int. 1*) and initial part of descending intestine showing typhlosole (*Int. 2*); labia (*Lab*) and upper edge of root of foot (*F*). × 20.

„ 24. Horizontal section at the level of left auricle (*Au.l*), through ventricle (*V.*), showing auriculo-ventricular valves (*V.a.v*), right nephridial cæcum (*R.n.c*), crystalline style (*C.st*), pedal retractor muscle (*Ret*); also the direct efferent blood channel from the left branchiæ to the heart by way of the common efferent branchial vessel (*C.br.eff*) and left auricle (*Au.l*). × 16.

„ 25. Transverse section through crystalline style sac (pyloric cæcum) showing characteristic uniformity in the length of the lining cilia (*C.st.cil*) and the concentric ringing which the style shows in section. × 90.

„ 26. Transverse section of second or descending section of intestine; showing form of typhlosole (*ty*). × 100.

„ 27. Section from typical glandular region of nephridium to show renal cells. × 320.

PLATE V.

„ 28. Vertical longitudinal section, a little to the left of the median line, through a three months old *Placuna*. Shows the emergence of the pyloric cæcum (sac of crystalline style, *C.st.c*), also pedal ganglion (*Ped.g*) below and close to the left cerebral ganglion (*Cer.g.l*). The section cuts the internephridial passage transversely (*I.n.p*) and shows the highly muscular character of the ventricle (*V*). × 12.

„ 29. Section of another individual cut in the same plane but well to right of the median line. Shows the entrance into the stomach of some of the principal ducts of the digestive gland (*D.gl.d*), the emergence of the intestine from the stomach, the continuity of the right nephridium (*Neph.r*) with the right nephridial cæcum (*R.n.c*), the situation of the accessory excretory organ (*Acc.ex.o*) at the most dorsal portion of the nephridium, and the crystalline style sac dividing the right nephridium into two ventral lobes (*Neph.r* and

Neph.r'). The succeeding serial section on the outer side misses the heart (*V*) which here is just touched superficially. × 12.

Fig. 30. A section belonging to the same series as that of Fig. 29, but nearer the middle line. It shows more clearly the structure of the right nephridium and its posterior cæcum, and their relation towards the crystalline style sac and the rectum (*R*). As the course of the former is slightly sinuous it appears as two discontinuous portions in this section (*C.st.s* and *C.st.s'*). × 12.

„ 31. Transverse section of the left nephridium (*Neph.l*) at the insertion of the retractor muscle (*Ret*) to show the much folded nature of the wall and the manner in which the left gill (*Br*) is suspended by a mesentery from its outer margin. × 20.

Note.—The individual sectioned was not over four months old; in adults the foldings of the nephridial wall are much more complicated and more numerous.

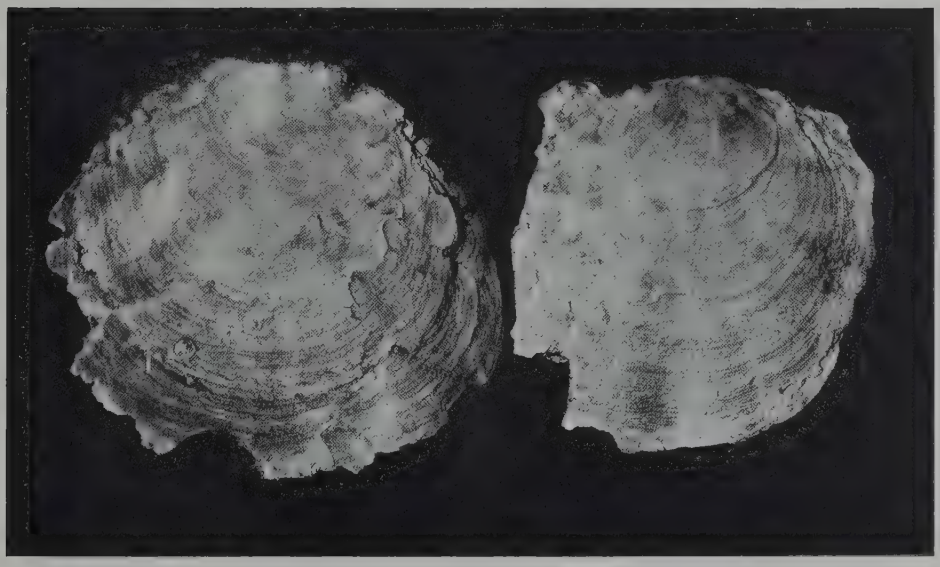
„ 32. Section of the mantle lobe showing the marginal and velar processes and the origin of the periostracum (*Periost*) within a deep narrow groove. × 80.

„ 33. Face view of three branchial filaments to show the method of interlocking by means of ciliated discs close to the free or ventral edges of the gills. × 120.

„ 34. A typical gill filament in transverse section to show the histological structure and the arrangement of cilia elsewhere than at the level of the ciliated discs. × 600.

Figs. 35 and 36. Two forms of ova as seen within the duct of the gonad. × 800.

Fig. 1.—Young *Placuna placenta* of three ages. × $\frac{3}{4}$.

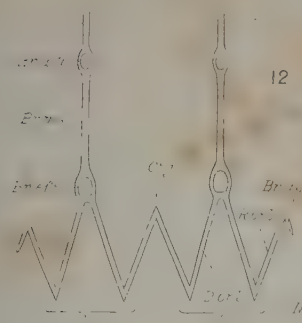


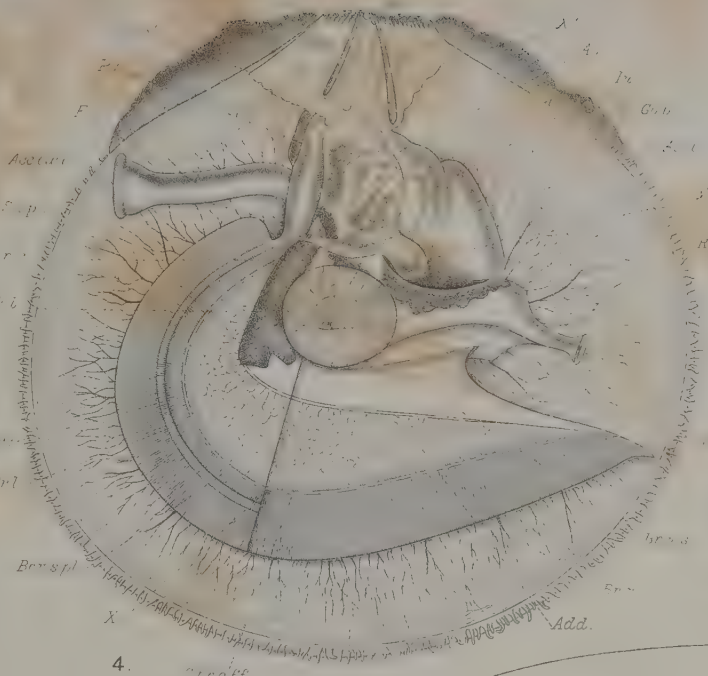
[*Photo by Vividha Kala Mandir, Baroda.*

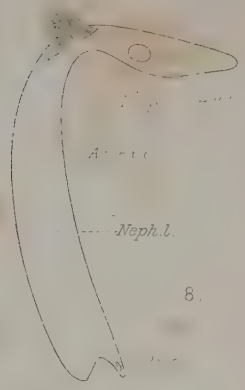
A B

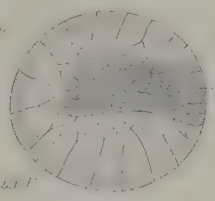
Fig. 2.—Two adult individuals, showing injuries inflicted by fishes. × $\frac{2}{3}$.

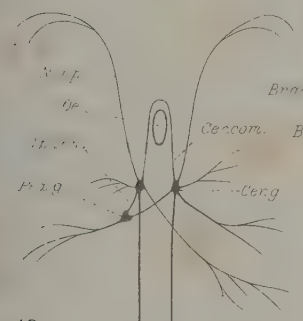
EXTERNAL APPEARANCE OF PLACUNA

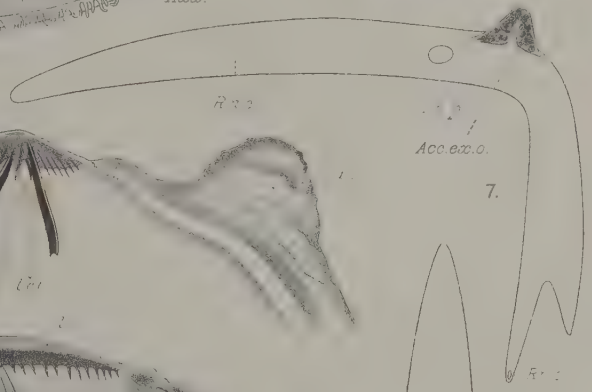


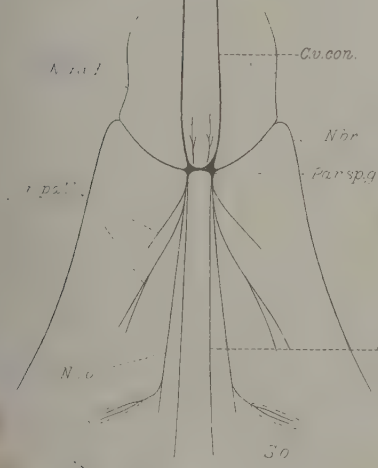


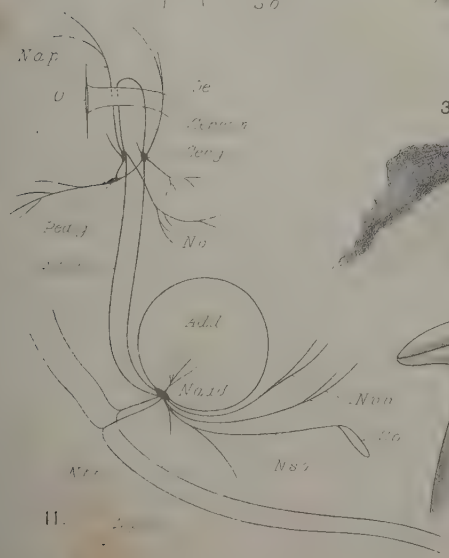


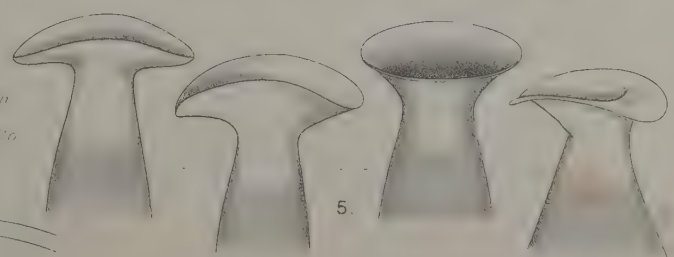


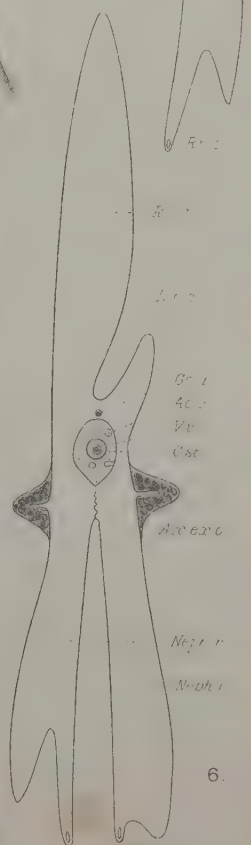






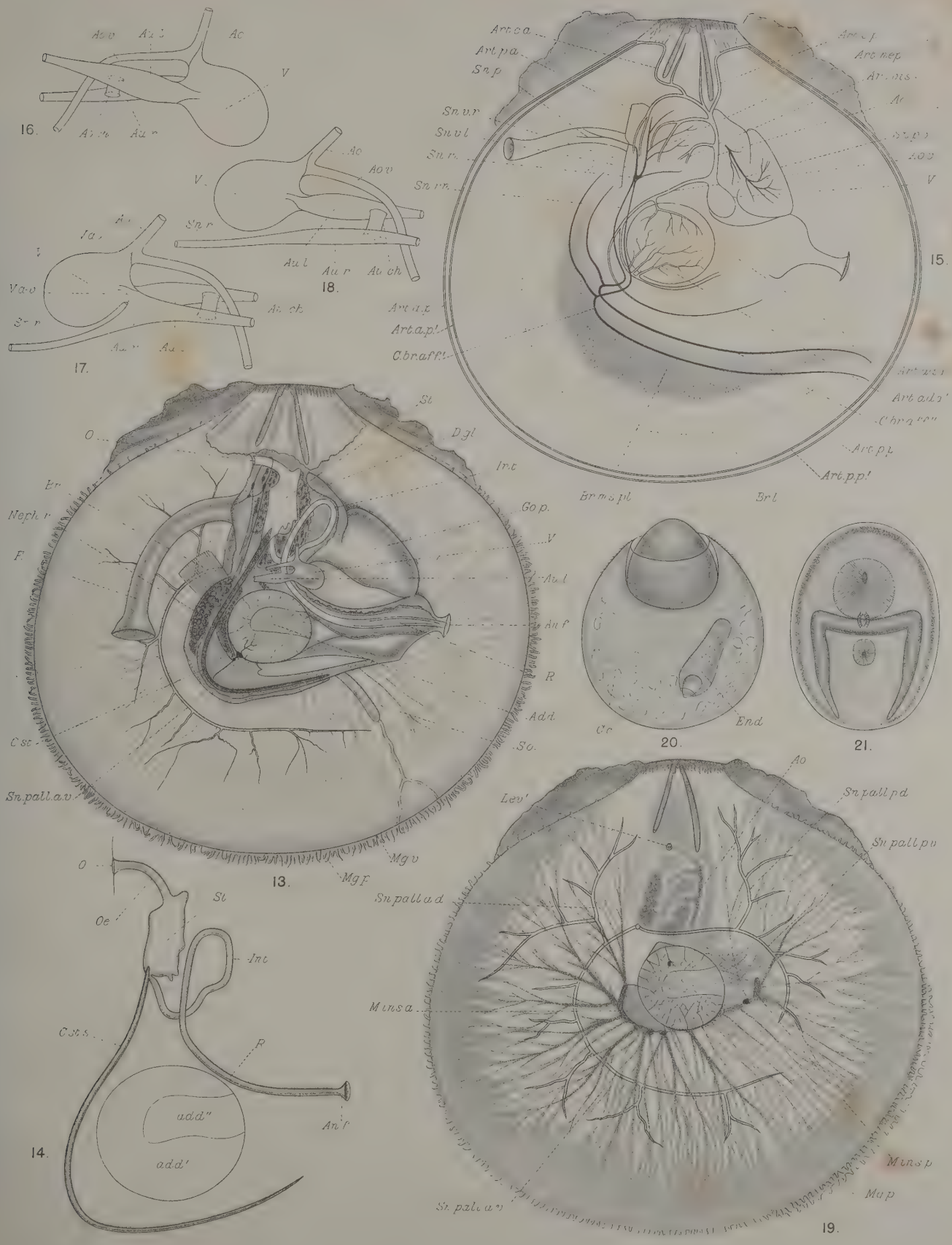






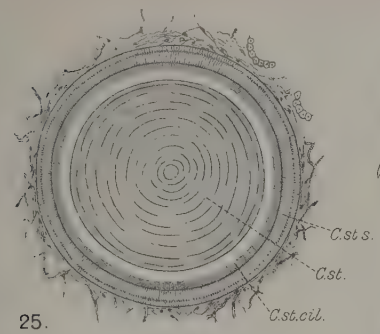
ANATOMY OF PLACUNA.

Edwin Wilson, Cambridge.



ANATOMY OF PLACUNA.

Edwin Wilson, Cambridge



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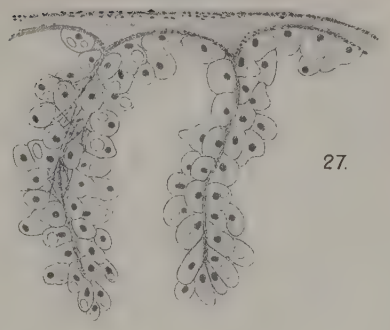

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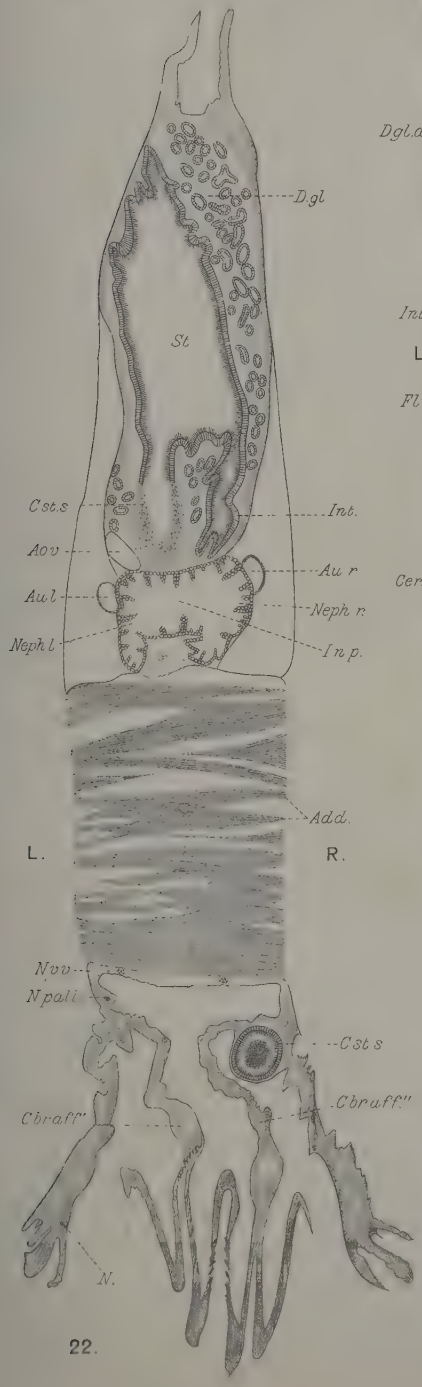

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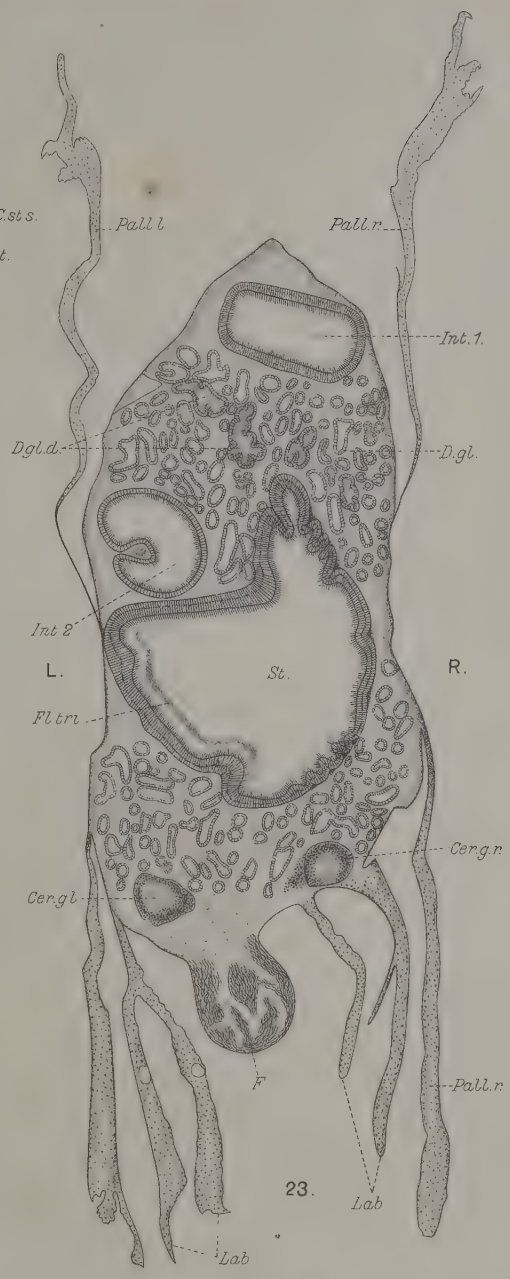

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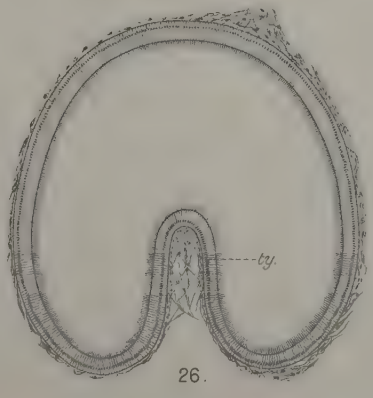

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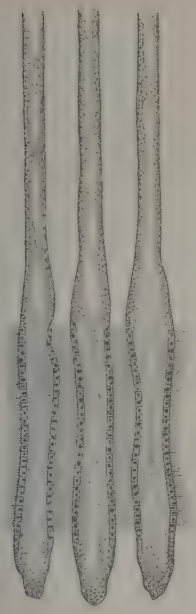

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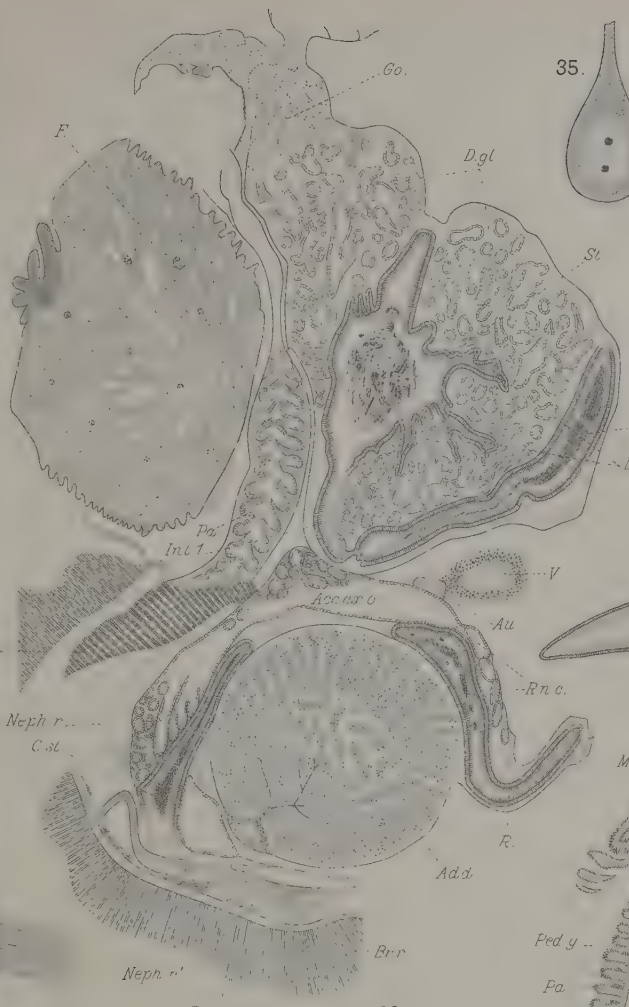

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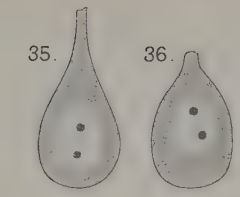

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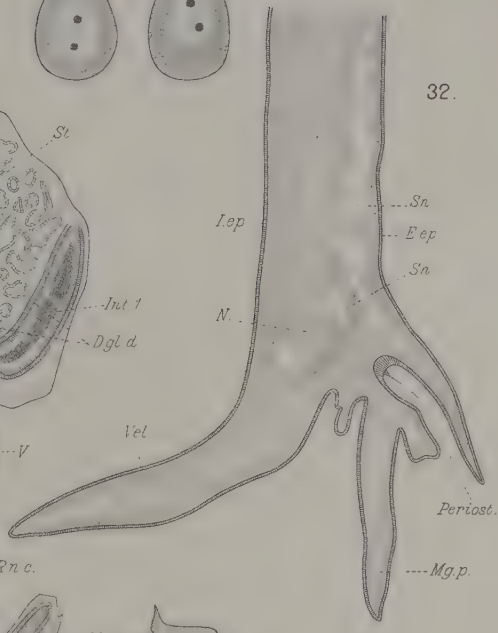

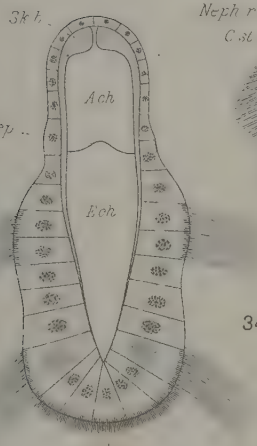

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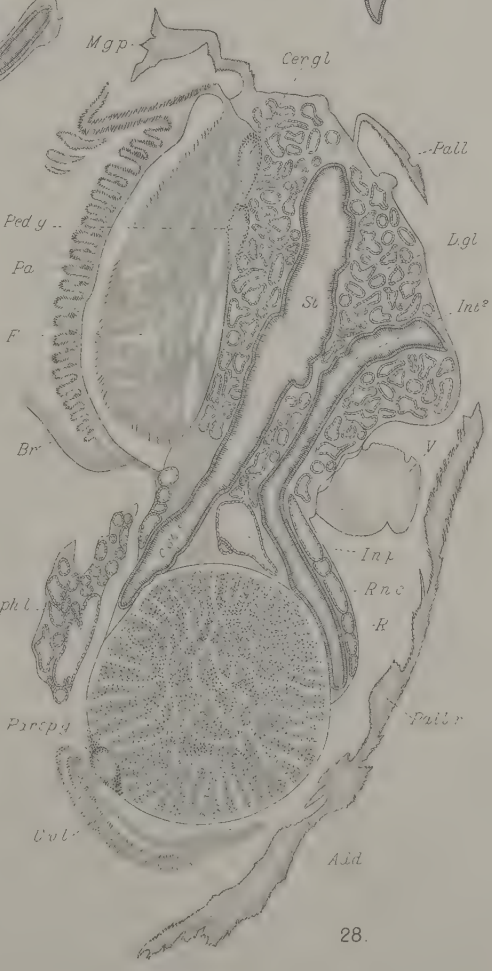

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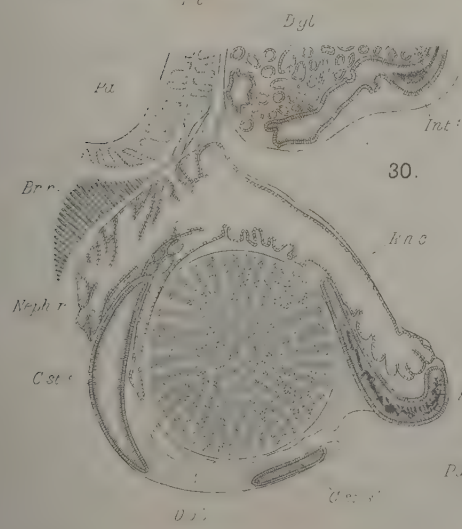

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31.

HISTOLOGY OF PLACUNA.

Edwin Wilson, Cambridge.

DESCRIPTION

OF A

NEW SPECIES OF PINNOTERES FROM PLACUNA PLACENTA,

WITH A NOTE ON THE GENUS,

BY

JAMES HORNELL, F.L.S.,

AND

T. SOUTHWELL, A.R.C.Sc., F.L.S.

[With One Plate.]

The material upon which the following description is based was obtained during a biological survey of the coast of Okhamandal in Kattiawar. The bays on the north-east seaboard of this district have a bottom composed of extremely soft mud, constituting an agreeable habitat for the window-pane oyster (*Placuna placenta*), which exists there in extensive beds. During the dissection of numerous individuals of this mollusc, large pea-crabs were found in nearly all cases. The large individual size, greatly flattened appearance, and preponderance in number of the males at once arrested attention as being conspicuously different from any species previously met with by the observer. Later research confirmed the original impression that this form of *Pinnoteres* constitutes a new species; on account of the particular habitat wherein it is found the specific name *placunæ* has been considered appropriate.

The detailed description of the two sexes is as follows:—

Pinnoteres placunæ, n. sp.

Female.—Body soft and membraneous; carapace broader than long, circular in outline, smooth and greatly flattened dorso-ventrally; lateral margins entire; front broad, sharply truncated, and straight. Eyes, eye-stalks, and the whole of the orbit

hidden in a dorsal view. Eyes small. Orbits circular, eye-peduncles short. Antennæ minute and placed within the anterior hiatus of the orbit.

Chelipedes smooth, the movable fingers being slightly hairy, and as long as the palm.

Ambulatory legs slender and increasing in size posteriorly, except the fourth pair, which are smaller than the first pair.

Dactyli of the third and fourth pairs one and a half times as long as those of the first and second.

Dactyli of the last pair, hairy at the tips.

Abdomen seven-jointed, broadening considerably posteriorly.

Length of carapace 9 mm., breadth 11 mm.

Numerous females bearing eggs. Colour in formalin, dirty brownish red.

Male.—Carapace smooth. Front broadly triangular, short, and raised. Posterior, broad and sharply truncate. The oblique cervical grooves well marked and terminating just external to the orbits. Eyes small and visible in a dorsal view. Eye-peduncles very short. Antennules extremely minute. Antennæ long with peduncles backwardly projecting.

Chelipedes similar, short, and equal in length to the breadth of the carapace. Merus slightly longer than broad, with a rounded entire crest on its distal external face. Carpus slightly longer than broad, and curiously curved. Propodite longer than carpus, dactylopodite almost as broad as long and somewhat flattened. Fingers curved with a hiatus between them when closed, and hairy on their opposing surfaces. Succeeding legs slender. First pair approximately equal in length to the chelipedes, second pair longer than the first pair by slightly more than a dactylus, third pair longer than second pair by a dactylus.

Abdomen narrow, permanently flexed under the body, and narrowing posteriorly. First pair of abdominal appendages modified into long, cylindrical, rod-like bodies which project from beneath the abdomen.

Length of carapace 7·5 mm., breadth 9·5 to 10 mm.

Apart from sexual characteristics, the male differs markedly from the female in (1) its much smaller size and (2) the form of the rostrum.

Pinnoteres placunæ is characterised by being extremely flattened dorso-ventrally, by having the front of the carapace straight and broad in the female, and by the somewhat squarish outline of the carapace.

Habitat.—Commensal within the mantle cavity of *Placuna placenta*, Balapur and Rann Bays in the Gulf of Kutch, India ; abundant.

Rare in the same species of Lamellibranch in Tampalakam Bay, near Trincomalee, Ceylon, one to three fathoms.

Out of twenty adult Placunæ examined alive and hailing from Balapur Bay, Beyt Island, in the Gulf of Kutch, one shell only was without any pea-crab commensal.

Of the rest,

10	individuals	contained	1 female each;
2	,,	,,	1 female and 2 males each;
2	,,	,,	1 female and 1 male each;
1	,,	,,	12 males;
1	,,	,,	11 males;
1	,,	,,	3 males;
2	,,	,,	2 males each.

Besides these particular individuals, a large number of others of the same age were examined without note being taken of the exact numbers of pea-crabs respectively contained; scarcely any were found without one or more of these guests free within the mantle cavity. The majority were located in the neighbourhood of the anus.

Immature shells, as is natural, less frequently revealed the presence of commensal pea-crabs; when they did occur the crabs were more or less immature. It would seem that the crabs grow towards maturity concurrently with their hosts.

Placunæ from Ceylon rarely contain this commensal. One large female was, however, taken by one of us some years ago from a large Placuna fished at Tampalakam Bay, proving the geographical range to extend from the Gulf of Kutch to Ceylon.

A large number of Placunæ obtained from Tuticorin in South India yielded no pea-crabs. It would be interesting to learn the reason why these crabs are so abundant in one locality, so rare in the others. Environment appears generally to be identical in all three localities.

Borrodaile, in his report on Marine Crustacea in "The Fauna and Geography of the Maldives and Laccadives," vol. i., p. 428, refers to the Pinnoteridæ as being "small symbiotic crabs with very small eyes and orbits. Body usually more or less rounded; carpopodite of the third maxilliped does not articulate at or near the inner angle of the meropodite. Body usually square or squarish. Male openings sternal."

Laurie, describing a new species of *Pinnoteres* from the Gulf of Mannar ("Ceylon Pearl Oyster Reports," vol. v.), characterises the carapace of *Pinnoteres margaritiferæ* as "circular, calcified, smooth and polished. It is flattened a good deal, though a little convex."

A specimen of *Pinnoteres abyssicola*, Alcock and Henderson, was taken from a living individual of a large species of lamellibranch (*Lima indica*, E. A. Smith) dredged off the coast of Travancore at a depth of 439 fathoms. This specimen, which was a female with eggs, had "the carapace as long as broad, circular and smooth. The whole of the eyes and eye-stalks, and almost the whole of the orbits, visible in a dorsal view."

A specimen of *Pinnoteres villasulus*, Guerin Minivelle, found within the pearl oyster in Torres Straits and presented to the *Challenger* staff (*Challenger Reports*, vol. xvii.) had the front "deflexed and trilobate."

In the case of *Pinnoteres ostreum*, recorded from the East Coast of America, the female *only* is commensal with *Ostrea virginica*, whilst the male is free-swimming.

It is interesting to note from the preceding that only in the case of *Pinnoteres margaritiferæ* is the carapace referred to as being much flattened.

Specimens of *Pinnoteres placunæ*, n. sp., are *particularly* characterised by being so compressed dorso-ventrally as to be *quite flat*. This, of course, is exactly what one would expect to find in a species commensal with a bivalve in which the valves of the shell are so closely approximated as in the case of *Placuna placenta*. In this connection it is interesting to note that *P. placunæ* and *P. globosus* form two extremes in the form assumed by the body. As we have seen, *P. placunæ* is remarkably flattened, whereas *P. globosus*, as the specific name implies, is globular in appearance. These facts serve to indicate the plasticity of the members of the genus and the readiness with which they adapt themselves to their surroundings.

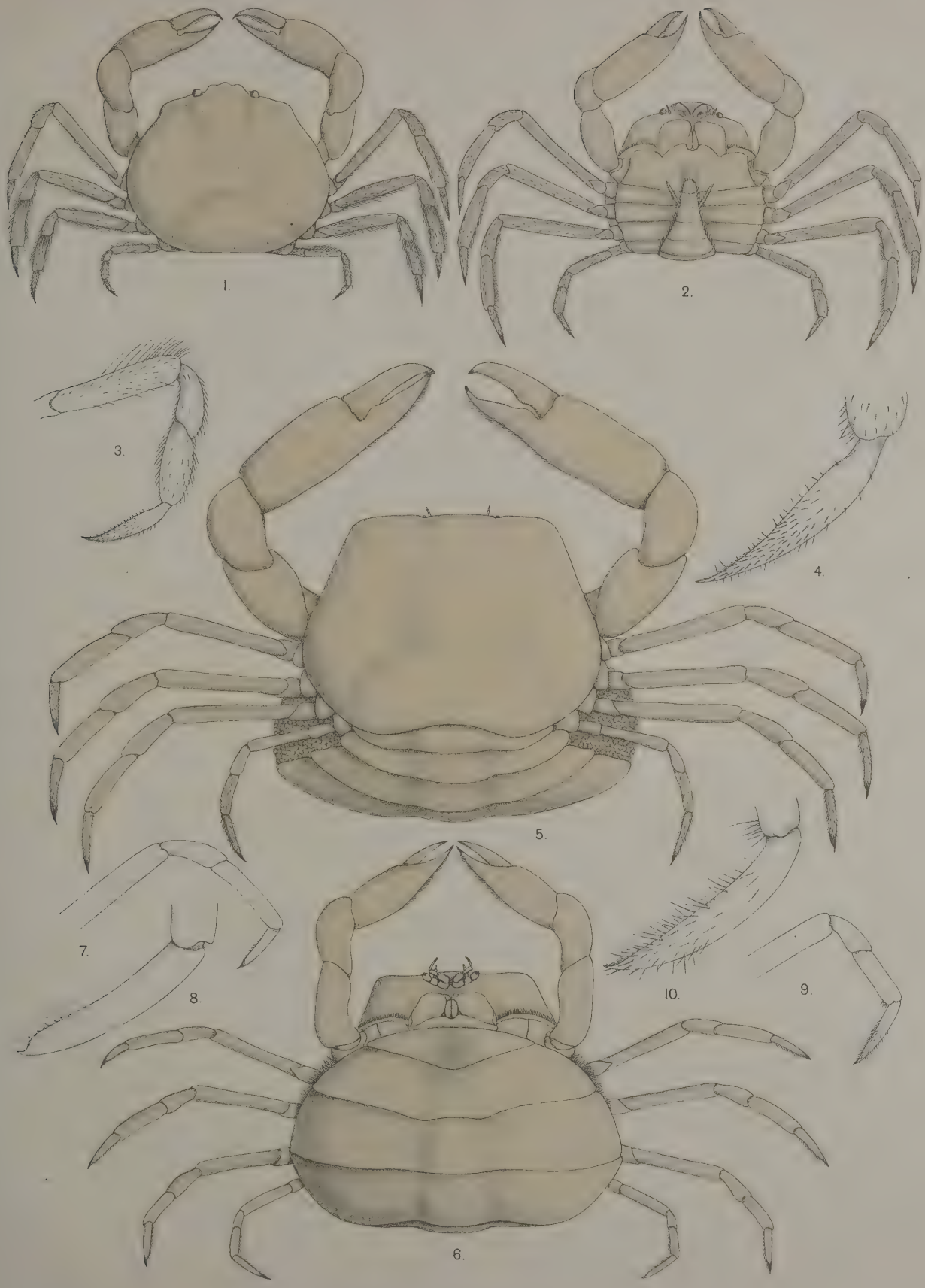
It will be noticed that *P. pisum* is more or less cosmopolitan, having been recorded from England and from New Zealand; it would seem that other species of *Pinnoteres* are local variations of *P. pisum*. The specific and restricted distribution of certain of the species, such as *P. margaritiferæ* and *P. placunæ*, appears to confirm this idea.

The following is a list of the species of *Pinnoteres* recorded up to date, as far as we have been able to ascertain, with their respective hosts and the localities where they occur :—

Species.	Host.	Distribution.
P. pisum (Tennant)	*Modiola*, sp.	Mediterranean; New Zealand
P. margaritiferæ, Laurie	Ceylon Pearl Oyster (*M. vulgaris*)	Ceylon Pearl Banks
P. placunæ, Hornell and Southwell	*Placuna placenta*	Gulf of Kutch
P. rouxi, M. Edwards	?	Indian Seas
P. villosus, Guir.	?	?
P. parvulus, Stimpson	*Pinna*, sp.	New Zealand
P. globosus, Hemb. Jaques (= *obesus*, Dana)	*Meroe quadrata* and *Cythrea*, sp.	China Seas
P. velerum, Bosc.	—	—
P. abyssicola, Alcock and Henderson	*Lima indica*	Off Travancore, 439 fms.
P. villasulus, Guerin Minivelle	Pearl Oyster	Torres Straits
P. edwardsi, De Man	*Ostrea*, sp.	King Island Bay
P. pecteni	*Pecten*, sp.	E. coast of North America
P. ostreum	*Ostrea virginica* (male free-swimming, female only in oyster)	Do.
P. purpureus, Alcock	*Ostrea*, sp.	Andaman Islands
P. mactricola, Alcock	*Mactra violacea*	Hoogly River, India

EXPLANATION OF PLATE.

Fig. 1. Adult male *Pinnoteres placunæ*, n. sp. Dorsal view. × 5½.
„ 2. Ventral view of same. × 5½.
„ 3. Fourth walking leg of a male, right side. × 9.
„ 4. Dactylus of same, more highly enlarged.
„ 5. Dorsal view of an adult female carrying ova. × 8.
„ 6. Ventral view of same. × 7.
„ 7. Third walking leg from right side of a female. × 9.
„ 8. Dactylus of third walking leg of a female. × 17.
„ 9. Fourth walking leg from right side of a female. × 9.
„ 10. Dactylus of same. × 17.



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PINNOTERES PLACUNÆ, n. sp.

Edwin Wilson, Cambridge.

REPORT

ON THE

ANOMURA

COLLECTED BY MR. JAMES HORNELL

AT

OKHAMANDAL IN KATTIAWAR IN 1905-6,

BY

T. SOUTHWELL, A.R.C.Sc. (London), F.L.S.,
Naturalist to the Ceylon Company of Pearl Fishers, Limited.

[With One Plate.]

The present collection of Anomura, though but a small one, is exceedingly interesting for two reasons. First, as showing the considerable degree of variation present in certain species of the family Galatheidæ, and secondly, the large size of many individuals conveys to us some idea under what luxuriant conditions they must have lived.

In all there are thirteen species, representing seven genera, and two of these species are new, viz., *Porcellana gaekwari* and *Polyonyx hendersoni.*

The following is a list of species in the collection :—

Diogenes investigatoris, Alcock.
Clibanarius infraspinatus, Hilgendorf.
Clibanarius humulis, Dana.
Porcellana serratifrons, Stimpson.
Porcellana gaekwari, n. sp.
Porcellana tuberculosa, Milne-Edwards.

[1] The opportunity afforded by this report has been taken advantage of to include reference to several species from the Ceylon Pearl Banks, not previously described from that district.—T.S.

Polyonyx obesulus (White).
Polyonyx hendersoni, n. sp.
Petrolisthes armatus (Gibbes).
Petrolisthes bosci (Andouin).
Petrolisthes, sp.
Galathea elegans, White.
Munida spinulifera, Miers.

All these species are shallow-water forms, and in most cases were taken in under four fathoms.

With the exception of *Porcellana tuberculosa*, and the two new species, all the forms herein described have previously been recorded from the Indian Ocean. Both the new species included in this paper, viz., *Polyonyx hendersoni* and *Porcellana gaekwari* were collected by me from the Ceylon Pearl Banks.

A noticeable feature of the collection from the Gulf of Kutch is the preponderance of Galatheidæ over the Paguridæ, both in point of species and numbers. This fact is to be correlated with the peculiar nature of the fauna on the ground where the collection was made. The commensal habits of many genera included in this family are well known. Generally, Galatheids and Munidids are to be found crawling over the surface of dead coral, or under rocks, or upon living coral, but the more brightly coloured representatives of the former genera—such as *Galathea elegans* and *Galathea deflexifrons*—are more commonly to be found commensal with similarly coloured species of Comatulids.

On the other hand, the members of the genera *Polyonyx* find a home in the large exhalant cavities of many species of sponge, and they are but rarely found elsewhere. The species of *Porcellana* proper are likewise more or less commensal. Their commonest habitat is amongst the short stumpy branches of different species of *Spongodes*, many having pink or dark purple tips, and the colour markings of the Porcellanids commensal thereon agree with those of the partner so well that they are often difficult to see.

The Kutch collection was made on ground rich beyond description in corals, sponges, crinoids, and such alcyonarians as *Spongodes*, and it is therefore natural to find a predominance of such forms as usually occur in such a habitat.

The classification of the Galatheidæ adopted in this paper is the one adopted in the Report on the *Challenger* Anomura, and the definitions of the genera here given are also those therein given by Henderson. In the group Paguridea, however, the classification adopted and the characters given are those given by Alcock in his *Indian Decapod Crustacea*. In some instances I have had difficulty in satisfactorily referring some of the Kutch genera to their proper place. Especially was this the case in the family Porcellanidæ, and it would appear that, with our extended knowledge of this group, a more suitable and precise method of classification

might be initiated, even though some of the genera are certainly very nearly related. The descriptions given of many species of Porcellana are much too short to be of any real value, and render the work of identification not only unsatisfactory, but almost impossible. No doubt, however, much of the difficulty referred to above has been due to the difficulty of access to necessary literature.

During the examination of this Kutch collection I have had the inestimable advantage of being so situated that by far the most of the species recorded in this paper have been accessible to me in quantity, and in a living condition, from the Ceylon Pearl Banks.

No fact has struck me so forcibly during the examination of this collection, as the extent of the variation characteristic of many species. Some species within a genus may be distinguished as being more stable than others. Spines are particularly liable to variation; so, in less degree, are colour markings. Many of these variations are noted in the text. This fact serves to indicate how inaccurate may be descriptions of new species made from a very few specimens—and possibly young forms.

I cannot close without expressing my indebtedness to Mr. Hornell for his help in many ways, for placing this collection in my hands, and for providing opportunities for studying fresh material under conditions in which it was a pleasure to work.

ANOMURA.

PAGURIDES.

Family: Paguridæ.

Paguridæ: Dana (7), Stimpson (34), Henderson (19), Stebbing (33), Ortmann (29), Bouvier (6), Milne-Edwards and Bouvier (10), Alcock (2).

Paguroidæ: Boas (5).

Parapaguridæ: Smith (31), Henderson (19), Stebbing (33).

Diogenes, Dana.

Dana (7), Stimpson (34), Heller (16), Haswell (14), Henderson (19), Stebbing (33), Ortmann (29).

This genus is confined to shallow water, and is characteristically Indo-Pacific. There are about thirty species, three of which occur along the shores of the Atlantic, one in the Mediterranean (solely), and the rest are purely Indo-Pacific. Many of the species are small and very variable. The outstanding features which characterise the genus are as follows:—

Abdomen soft, coiled, and well developed. Carapace elongate. Eye-stalks slender. Ophthalmic scales large and separated by a movable rostrum. Antennal acicle well developed, with the flagellum usually setose.

Chelipedes dissimilar, the left being much the greater. The fingers move in an oblique direction and have their tips calcareous and acuminate. The palp of the first pair of maxillæ has a recurved flagellum. Fourth pair legs subchelate, fifth pair chelate, both with corneous granules on their distal outer surface. Abdominal segments four in number, and situated on the left side, uniramous in the male and biramous in the female, except in the last one. The gills are phyllobranchs, and are thirteen in number on each side.

Diogenes investigatoris, Alcock.

Carapace fairly elongate, with the anterior and lateral edges serrulate.

Rostrum a simple non-serrated rod, tapering towards the free extremity, and equal in length to the ophthalmic scales. These latter have their free edges spinulose. Eye-peduncles shorter than the antero-lateral border of the carapace and reaching to the base of the terminal joints of the antennal and antennular peduncles. The antennal flagellum is slightly shorter than the carapace, and is coarse and setose. The antennal acicle does not overlap the base of the last joint of the peduncle. Left chelipede very much larger than the right, and a little longer than the carapace.

The outer surface of the hand is granulous, and there is a row of spines on the upper part of the outer surface of the palm. The legs are setose along their edges only and smooth elsewhere.

Three apparently young male specimens inhabiting shells of *Nassa glans* and *Sistrum spectrum*.

Length of carapace, 9 mm.; colour in spirit, dirty white.

Localities:—(1) Okha, 5 fms.; (2) off W. coast of Aramra.

Previously recorded from:—(1) Off Vizagapatam Coast, 20 fms. Alcock. (2) Ceylon Pearl Banks, 5 fms. Southwell.

Clibanarius, Dana.

Dana (7), Stimpson (34), Heller (17), Miers (26), Haswell (14), Henderson (19), Milne-Edwards and Bouvier (10), Stebbing (33), Ortmann (29).

Carapace elongate, broadened posteriorly, and calcified in front of the cervical groove, as in many other genera of Paguridæ. Rostrum short and distinct. Abdomen soft and spirally coiled.

Eye-stalks slender. Ophthalmic scales usually closely approximated. Antennal acicle short. Antennal flagellum long and non-setose. Exopodite of the three

maxillipeds have each a well-developed flagellum. The endopodite of the first maxillæ has a recurved flagellum.

Chelipedes usually similar and equal, or one may be slightly larger than the other. The fingers open and close in a horizontal plane, and their tips are corneous and spooned. The fourth and fifth pair of legs have a patch of thickened corneous granules on the outer surface near the tip.

No paired appendages in either sex, except those which form the tail fin. Biramous appendages are found on the left side on segments 2–5 inclusive.

This genus is a large one and comprises about 53 species. For the most part they inhabit tropical seas, but some extend into temperate waters. About half the number of known species are Indo-Pacific forms, five species occur along the Western Pacific Coast, ten species from the West Indies and neighbouring Atlantic Coasts, and six species from the Coast and Islands of North-West Africa. Some are Mediterranean. They are shallow-water and littoral forms (under 100 fathoms).

Clibanarius infraspinatus, Hilgendorf (20).

De Man (24), Ortmann (30), Henderson (18), Nobilli (28).

Carapace longer than broad, and bearing tufts of yellowish bristles, which are most numerous near the cervical groove, whilst others occur near the lateral borders, and on the calcified anterior part of the carapace. Rostrum very small and barely reaching to the base of the ophthalmic scales. These latter are small, and have their free edges spinose, setose, and approximated. Eye-stalks long, slender and sparsely setose, slightly longer than the antennal peduncles, and reaching to the middle of the terminal joint of the antennules. Antennal acicle setose and triangular in shape, with spines arranged along the internal edges and overlapping the terminal joint of the peduncle.

Chelipedes equal, similar, and very massive.

Upper and inner border of merus serrulate, and scattered vascular tubercles occur on the outer and under surfaces. A strong tooth occurs near the lower and inner border of the merus of the chelipedes. The extensor surface of the wrist, hand and fingers are covered with short stout conical tubercles, many of which bear a tuft of bristles. There is a hiatus between the base of the fingers when closed. The fingers meet terminally in a flat blackened corneous patch on the extensor surface. They open and close in a horizontal plane.

The second and third legs are smooth and not tuberculated, their joints are beset with setæ, and a few setæ occur on their extensor surfaces. The setæ are more numerous on the dactyli.

Colour in formalin, yellowish-brown.

Eye-stalks and second and third pair of legs bear longitudinal lines of colour.

Length of carapace of largest, 3·7 cm.

Three males, one in shell of *Murex tribulus.*

Localities:—(1) Beyt Island E. (Balapur); (2) off Dwarka.

Previously recorded from:—Tavoy, Museum collector; Red Sea, Ortmann; Mergui, de Man and Anderson; Singapore, Walker; Sydney, Ortmann.

Clibanarius humulis, Dana (7).

Heller (17).

Carapace longer than broad, and well calcified in front of the cervical groove. Rostrum very short and slender. Eye-stalks long and slender, equal in length to the antennal peduncles, and slightly shorter than the antennular peduncles.

Ophthalmic scales short, with their free edges spinose and approximated. The antennal acicle very slightly overlaps the base of the terminal joint of the peduncle, and bears numerous long setæ.

Chelipedes stout, equal, and as long as the carapace. Extensor surface of the wrist and fingers studded with conical tubercles, between which setæ occur. There is a hiatus between the bases of the closed fingers, which latter are blackened and corneous at their tips.

The second and third legs are much longer than the chelipedes, and are smooth and sparsely setose. The propodite of the third left leg is somewhat modified, its outer surface being a little flattened and its upper border crested. Dactyli also slightly flattened and terminating in sharp blackened claws.

Colour in formalin, dirty white; propodites, dactyli, wrist and fingers, light brown.

Two specimens—males.

Length of carapace of largest, 2·2 cm.

One specimen in shell of *Nassa granifera.*

Localities:—(1) Off Dwarka; (2) N. coast, Beyt Island.

Previously recorded from:—Betra Par, Laccadives, *Investigator*; Raratonga (West Pacific).

GALATHEIDÆ.

Family: Porcellanidæ.

Porcellana, Lamarck.

Lamarck (21), Stimpson (34), Haswell (14), Milne-Edwards (9).

Characters of the genus:—

Carapace suborbicular, or subovate. The length usually greater than the breadth. Frontal region prominent and dentate, the teeth usually well developed. Orbits deep.

Eyes usually large. Chelipedes moderately flattened. The carpus short, and usually provided with a single projecting lobe near the proximal end of the internal margin. The digits frequently contorted. Ambulatory limbs with the dactyli short and robust, terminating in a single claw.

Porcellana serratifrons, Stimpson.

Stimpson (34), Southwell (32), Henderson (19).

This species (which the writer has had many opportunities of examining, both from Kutch, and, in particular, from the Ceylon Pearl Banks, where it occurs plentifully) is extremely variable, a fact which, so far as I know, has not hitherto been sufficiently emphasised. So extensive are these variations, that it is impossible to give more than a general description of the species.

The front is composed of three lobes, of which the median one is rounded, and minutely serrate. The two lateral ones are much smaller, and acute, a few teeth, which are coarser than those on the median lobe, being present on their internal edge. The carapace is usually somewhat flattened, and is marked by a discontinuous, parallel transverse series of pubescent striæ. Edges of the carapace with a variable number of teeth. A few spines occur over the insertion of the antennal peduncles. A little posterior to these is a rounded lobe, bearing some small teeth. Some, or all, of the segments of the antennal peduncles bear single teeth on their internal face. Chelipedes equal or unequal, the left or right being the larger. The chelipedes, like the carapace, bear discontinuous rows of pubescent striæ. The inner angle of the merus is prominent and armed with teeth. A few teeth, usually two, occur on the internal edge of the carpus. The external edge may be entire, or bear one or two teeth.

The propodite of each chelipede bears a median dorsal carina, which may, internally, be entire, or toothed; the outer edge always toothed. Fingers curved and short.

Natural colour: dark uneven brownish-grey changing in spirit through brick red to colourless.

Very numerous specimens, males and females.

Average length of carapace, 10 mm.; average breadth of carapace, 9 mm.

Locality:—Off S.W. of Beyt Island, Gulf of Kutch.

Previously recorded from:—Hongkong, *Challenger* Expedition; Ceylon Pearl Banks, Southwell.

From the examination of some hundreds of specimens, the following facts and conclusions were arrived at:—

(1) That although the general form and outline of the carapace was consistent throughout, particularly the form of the rostrum, innumerable minor variations occur.

(2) That these variations are not usually sexual variations, nor merely due to differences of age.

(3) That the female is generally slightly broader, and of a darker colour—particularly in spirit specimens—than the male.

(4) That the occurrence of spines is quite irregular, and not to be relied upon for purposes of identification.

Porcellana gaekwari, n. sp.—Plate, figs. 1–3.

Carapace slightly longer than broad, convex from side to side, and from before backwards, and marked by discontinuous, transverse striæ. Lateral margins armed with a series of spines. There is a spine immediately posterior to the orbit, and one situated over each antennal peduncle. A little further back is a rounded lobe, bearing a few minute teeth, and posterior to this are three more spines.

The rostrum is short and deflexed, with a definite mesial furrow. It is made up of three lobes. The median lobe is much broader, and slightly longer than the two lateral ones. Its free edge is in the form of an exceedingly shallow V, and bears about four to six teeth. The lateral lobes are triangular, with their inner face dentate and their external edge entire.

Antennal peduncle long, cylindrical and three-jointed. First and third joints as broad as long. Middle joint one and a half times longer than broad. Antennal filament nude.

Eye-peduncle short, but extending beyond the edge of the carapace during life. In the living condition the eyes are colourless, but pigment develops after death.

Chelipedes twice as long as the carapace in adult specimens, their dorsal surfaces marked by transverse striæ, equal or unequal, the left or the right being very slightly the larger. Internal face of the merus minutely notched, its distal angle being produced into a lobe. Carpus of female slightly longer than broad, with a few teeth on its internal face, entire in the male, and sinuous.

Propodite long, and broadened distally, the posterior edge being smooth along two-thirds of its length, but denticulate distally. Movable finger curved, with a large tooth near its origin, and serrate along the rest of its inner border. The three following pairs of thoracic feet are approximately two-thirds the length of the chelipedes, and have the merus rather large, the carpus short, and as broad as long. Propodus three and a half times as long as broad and hairy on its anterior surface.

Dactyli short, curved, and multiunguiculate.

Length of carapace, 8 mm.; breadth, 7 mm.; length of chelipede, 17 mm.; length of first thoracic leg, 10 mm.

Natural colour: ground colour milky white. Carapace with a few symmetrical blotches of light brown. Rostrum light purple. Chelipedes similar to carapace, but movable finger light purple. Walking legs light purple.

Seven specimens, one male and six females, five of the latter bearing eggs, and one being a young specimen.

Locality:—Challai Paar, Gulf of Mannar, four and a half fathoms; bottom, sand. Found commensal on a species of *Spongodes*, having dark purple tips.

This species bears a general resemblance to *Porcellana serratifrons*, but differs from it very definitely in the following particulars:—

(1) The median lobe of the rostrum is *slightly* concave instead of rounded.

(2) The propodite of the chelipede is smooth.

(3) The dactyli of the thoracic feet are multiunguiculate.

This species appears to be related to *Porcellana nitida*, Haswell, but his description is so short and incomplete that it is inconclusive.

The median rostral lobe of *P. nitida* is said to be "much longer than the other," without any further description. Moreover, *Porcellana gaekwari*, n. sp., has the rostrum spinose. The carpus of the chelipede in *P. nitida* has a sharp entire internal crest. Only the males of *P. gaekwari*, n. sp., have the carpal crest entire.

This species is variable. The young specimen had the chelipedes only one and a half times as long as the carapace, and equal. In others, the chelipedes were sometimes equal, or the left or right was slightly the larger.

The spines on the internal edge of the carpus of the chelipedes of the female were variable in number, as shown in the following table:—

Specimen.	*Carpus of R. Chelipede.*	*Carpus of L. Chelipede.*
1	3 spines	2 spines and many minute ones distally.
2	4 „	5 spines.
3	4 „	4 „
4	8 „	5 „
5	7 „	5 „
6	3 „	4 „

This species undoubtedly belongs to the genus *Porcellana*, as defined in the Report on *Challenger* Anomura.

A noticeable feature was, that in the fresh condition the eyes were non-pigmented, the pigment only developing after death, and even then not being very pronounced. Amongst the characteristics of this genus is the fact that the dactyli of the ambulatory limbs terminate in a single claw, and also that the first joint of the antennal peduncle is joined to the margin of the carapace.

Porcellana gaekwari, n. sp., differs markedly in both these particulars. However, its general characteristics are more those of a *Porcellana* than of any other genus, and it is accordingly placed here.

This species is named in honour of H.H. the Maharaja Gaekwar of Baroda, to whose liberality is due the carrying through of the investigation of which the present report forms part.

Porcellana tuberculosa (Milne-Edwards).—Plate, fig. 4.

Petrolisthes tuberculosa, Milne-Edwards (9).

A single specimen (female) is doubtfully referred here. The description of this species by Milne-Edwards, in his *Histoire Naturelle* (which is the only one available), is very short, somewhat indecisive, and no figures are given. Milne-Edwards' description is as follows :—

> "Carapace slightly convex, and pilose on the sides, covered with short filigerous wrinkles, and presenting on the sides some small tubercles.
>
> "Front deeply divided into three lobes of which the median one is large and round, and is guttered with a profound median furrow, and the lateral ones are straight, obtuse, and directed obliquely outwards. Anterior feet very large. Carpus armed on the anterior edge with several teeth, of which two are pretty large, and present above, three longitudinal series of tubercles, separated by two furrows. Median series most numerous and elevated. Similar tubercles on face of hands. Length 16 mm. Habitat, Chili."

The Kutch specimen agrees with Milne-Edwards' description in the following particulars :—

(1) The carapace is pilose on the sides and presents small tubercles laterally.

(2) The front as in foregoing description.

(3) The carpus of chelipedes has three longitudinal dorsal series of tubercles, separated by two furrows. Median series most numerous and elevated.

(4) The presence of tubercles on the hands.

It differs in the following particulars :—

(1) The transverse filigerous wrinkles on the carapace are absent.

(2) The carpus of the chelipedes only armed with one tooth proximal and internal, and another distal and external.

(3) The chelipedes are not covered with a dense down.

Assuming the species to be the same, the Kutch specimen possesses the following characteristic points :—

(1) The palp of the third maxillipede is enormously long and hairy.

(2) The right chelipede is slightly larger than the left.

(3) The merus of each thoracic leg is characterised by being markedly broad.

Milne-Edwards gives the length as eight lines ($\frac{2}{3}$ in.). I am unable to determine whether this measurement is simply that of the carapace or the whole animal.

The description of the Kutch specimen is as follows:—

Carapace slightly longer than broad, moderately flattened, and markedly tuberculated, with deep intervening sulci, the granular tubercles being largest towards the anterior. Cervical grooves well marked and terminating behind each orbit. Rostrum short, deflexed, and broadly triangular, its extremity being marked by three large tubercles, of which one is median and advanced, and the other pair lateral. Lateral margins of the carapace entire and hairy. Outer orbital angle projecting. Epibranchial spines absent. Eyes large and protruding. Eye-peduncles short; antennules minute. Antennæ projecting laterally, the first joint not extending to the edge of the carapace, and having a crest on the distal anterior edge. Palp of the third maxillipede very long, hairy, and extending beyond the extremity of the antennules. Chelipedes depressed, unequal, the right one being slightly the larger, and twice as long as the carapace.

Merus short, and roughly triangular, with a small tooth on its internal distal angle, and a few scattered granules on its dorsal and external face. Carpus two-thirds as long as the carapace, and half as broad as long. Its dorsal surface is marked by numbers of tubercles of unequal size and roughly arranged in three rows, separated by two shallow furrows. A small spine occurs proximally on its internal edge and another one on its distal external edge. Ventral surface smooth. Propodite narrow proximally, widening distally, and wedge-shaped from side to side, with the narrow end external; its dorsal surface is marked by a number of tubercles of unequal size, and roughly arranged in rows. A few short hairs occur on its external edge. Ventral surface smooth. Fingers short, slightly curved, approximated when closed, and tuberculated. A pad of short matted hairs occurs ventrally on their proximal ends. The three succeeding pairs of thoracic feet equal, short, flattened, hairy along their edges, and tuberculated along their dorsal surface. Merus very large, and almost as long as the three succeeding joints, and three-fifths as broad as long. Carpus, propodus and dactylus of each thoracic leg slender.

Last (fourth) pair of thoracic legs very slender, and folded along the sides of the body, abdomen flexed under the body and slightly hairy, the hairs arising from the edges of the terga and from isolated dorsal areas.

One female with eggs.

Length of carapace, 10 mm.; breadth of carapace, 9 mm.; length of right chelipede, 20 mm.; length of left chelipede, 18 mm.; length of first thoracic leg, 12 mm.; length of merus of first thoracic leg, 5 mm.

Colour in formalin: milky white.

Locality:—South-west coast of Beyt Island.

Polyonyx, Stimpson.

Stimpson (34), Henderson (19), Henderson (18), Southwell (32).

Carapace suborbicular, and convex, the breadth slightly greater than the length. Front but little produced, with an almost straight margin. First joint of the antennular peduncle smooth. The corresponding joint of antennal peduncle greatly elongated. Eyes of small size. Chelipedes smooth with the merus broad. Dactyli of the ambulatory limbs short and furnished with two or more well-developed claws.

Polyonyx obesulus (White).—Plate, fig. 5.

Southwell (32), Henderson (18), Henderson (19).

Carapace smooth and convex, the breadth slightly greater than the length. Rostrum very slightly developed, obtusely rounded and deflexed in such a way that it is not seen in a dorsal view. First segment of the antennal peduncle long. Chelipedes equal, or the right or left the larger. Outer surface of the hand smooth. Merus of the chelipedes has its internal distal angle produced into an entire lobe. Carpus longer than broad. Propodite as broad as long. Fingers gaping or not, and mostly curved. The ambulatory dactyli are triunguiculate.

Localities:—(1) Kiu, Okhamandal, low water; (2) South-west coast, Beyt Island. One specimen from each locality.

Breadth of carapace, 8 mm. Natural colour: brownish-grey, turning red in spirit.

Previously recorded from:—Amboina, de Man; Singapore, Walker; N. Australia, Miers; Ceylon Pearl Banks, Southwell; Madjicosima Is., White; Flinders Passage, Henderson.

This species is closely related to *P. biunguiculatus*, and De Man suggested their union into one, an idea, however, which was opposed both by Miers and Henderson.

In a former paper on the Anomura of the Ceylon Pearl Banks, I remarked that *P. obesulus* and *P. biunguiculatus* "seem so closely related that it is difficult to believe that they are distinct. Some of our Ceylon specimens seem intermediate in their character."

Since the preceding statement was written I have had many opportunities of examining numbers of fresh specimens from the Ceylon Pearl Banks, where the species occurs plentifully in shallow water, usually inhabiting the large exhalant apertures of a species of *Hippospongia*, or found hidden in the cavities of rock or dead coral.

The two principal points in which *P. obesulus* differs from *P. biunguiculatus* may be summarised thus:—

P. obesulus:	*P. biunguiculatus:*
(1) Median frontal projection obtusely rounded and but little projecting.	(1) Median frontal projection prominent and acute.
(2) Ambulatory dactyli tri-unguiculate.	(2) Ambulatory dactyli bi-unguiculate.

I am now convinced that these differences are sufficiently stable to be specific—a conclusion arrived at after examining some hundreds of specimens of *P. obesulus.* At the same time I would here remark that the aforesaid points of difference are liable to a little variation. In one or two adult specimens of *P. obesulus,* with typically triunguiculate dactyli, the rostrum was scarcely obtuse, whilst in others it was almost straight. Again, one specimen was found with two of the dactyli on the walking legs typically biunguiculate, and in the other specimens the small proximal claw itself was noted to vary in size.

Polyonyx hendersoni, n. sp. (18)—Plate, figs. 6–9.

Carapace more convex from front to back than from side to side, broader than long—the greatest breadth being anterior—smooth dorsally, but lineolate along the posterior lateral borders. Rostrum sub-acute, rounded, only slightly projecting, and not visible in a dorsal view. Chelipedes variable, the left or right being the larger. Merus with a small tuberculated lobe on its distal internal face. Carpus as broad as long, strongly tuberculated, its internal edge produced into a rounded lobe bearing a few blunt teeth, and having a ventral entire carina. Propodus small proximally, widening distally, the length slightly greater than the breadth, tuberculated dorsally, smooth ventrally. Fingers curved or not, with a hiatus between them when closed, or not. The ambulatory dactyli are four-clawed, the terminal claw being slightly longer than the penultimate one, and the two proximal ones being minute. Ambulatory legs bear short, matty hairs on their anterior edge.

Length of carapace, 6 mm.; breadth ot carapace, 8 mm.

Natural colour: varying shades of brick red.

Locality:—South of Adams Bridge, Ceylon, eight and a half fathoms.

Found along with *P. obesulus* inhabiting the cavities of sponges, dead coral and rock. Several specimens, males and females, many of the latter bearing eggs.

This species is the one doubtfully referred to as *Polyonyx tuberculosus* by Henderson in his "Indian Carcinology." After giving a short description of it without naming it, he says, "this species is certainly distinct from *P. obesulus* or *P. biunguiculatus,* and as de Man represents his species with the carpus smooth above, and with very few tubercles present on the hand, our specimens may also

be distinct from *P. tuberculosus.* The ambulatory dactyli of the last species are not described by de Man. I have noticed in one or two specimens of *P. obesulus* a slight tendency towards tuberculation of the hand, chiefly in young individuals, but our species may be distinguished from this variety by the greater tuberculation and the different ambulatory dactyli. De Man had only a single small specimen, and it may have belonged to this variety of *P. obesulus,* in which case a new name will be necessary for the form, which is here briefly characterised."

Unfortunately, I have been unable to obtain de Man's description of *P. tuberculosus,* but the complete tuberculation of the carpus, and propodite, of our specimens, would almost alone be a point of sufficient distinction between the two specimens. Many individuals of *P. hendersoni,* n. sp., were examined, and the tuberculation of the carpus and propodus were found constant in every specimen. In one specimen the dactylus of one of the thoracic legs bore four small proximal spines instead of two. There can be little doubt, however, that *P. hendersoni,* n. sp., is a quite distinct species, and I have pleasure in naming it in honour of Dr. J. R. Henderson, who first described it, and whose careful work on the Anomura in general is so well known.

Petrolisthes, Stimpson.

Stimpson (34), Miers (26), Haswell (14), Henderson (19).

Characters of the genus :—

Carapace subovate, depressed, the length slightly greater than the breadth. Frontal region triangular, usually depressed, with the antennal peduncle remarkably short. Chelipedes broad and flattened, the carpus of moderate length, and often provided with teeth on the inner margin. Ambulatory limbs with the dactyli short and robust, terminating in a single claw.

Petrolisthes bosci (Audouin).

Porcellana boscii, Heller (15).
Petrolisthes boscii, de Man (25).
Porcellana rugosa, Milne-Edwards (9).

The front is prominent, triangular and deflexed, presenting a median furrow. The carapace is depressed, and slightly longer than broad. Margins entire and terminating anteriorly in an acute epibranchial spine. The surface is marked by a very noticeable mosaic, and by the strong development of granulate, filigerous, elevated, irregular lines, which are visible to the naked eye. Chelipedes equal, and beautifully sculptured like the carapace. The merus is armed with three spines at its distal extremity, one internal, one external, and one ventral and median. Carpopodite armed internally with a varying number of large spines (usually three or four), and externally with a

serrate crest, arising about the middle of its length, and increasing in size distally. Ventrally and internally the carpus bears an entire carina. Carpus twice as long as broad, and slightly shorter than the carapace. The fingers are straight, and there is no hiatus between them when closed. The ambulatory legs are slightly hairy, the carpus robust and flattened.

Colour in formalin, a lovely and characteristic mosaic of mottled maroon.

It is interesting to note that no mention whatever is made of the natural colour either by Henderson in his *Contribution to Indian Carcinology* (18), or by de Man in the *Crustacea of the Mergui Archipelago* (24). I have been unable to obtain Audouin's original description. However, these colour markings are most characteristic, and quite different in nature from anything I have previously seen. The Kutch specimens were preserved both in formalin and in spirit, and in neither case have the colours suffered any change, even after the lapse of two years.

This species appears to be closely related to *P. dentata* (Milne-Edwards), from which it differs in the peculiar and stronger development of the filigerous lines along the carapace, and also in the inner margins of the fingers being hairy, and the spine on the upper exterior margin of the merus being acute and not obtuse.

Two specimens, one male and one female.

Dimensions :—

	Kutch specimen.	De Man's specimen.
Length of cephalothorax	1·4 cm.	$8\frac{3}{4}$ mm.
Breadth ,, ,,	1·3 ,,	$8\frac{1}{3}$,,
Length of carpopodite	1·0 ,,	$5\frac{2}{3}$,,

From these measurements it will be noticed that the Kutch specimens are very large, being approximately two-thirds larger than those examined by de Man.

I have observed this species living in the cavities of certain sponges, and on the branches of *Spongodes*, sp., on the Ceylon Pearl Banks.

Locality:—Hanuman Dandi Reef, Beyt.

Petrolisthes armatus ? (Gibbes).—Plate, fig. 10.

Porcellana armata, Gibbes (12).

Petrolisthes armatus, Stimpson (34 and 35).

I doubtfully refer a damaged specimen of this genus to the species *armatus*, not being able to refer to Gibbes' original description, or to Stimpson, and no figure being available. The carapace is slightly flattened, longer than broad, and glabrous. There is no epibranchial spine. The front is broadly triangular and round, deflexed with a mesial furrow. The eyes are large. The chelipedes are equal, and two and a half times as long as the carapace. The merus has a short acute spine at its internal distal angle, and another one ventral and external. The carpus is almost as long as the carapace, and bears three teeth along its internal face, and a ventral internal and

external crest. The palm is broad and round, outer surface of hand not serrate. Fingers acute, curved and shorter than the palm, with a small hiatus between them when closed. Ambulatory legs missing. Colour in spirit : dirty milky white.

Locality :—South of Chindi Reef, Gulf of Kutch, 6–10 fathoms.

It is a Floridian and West Indian species, but has also been recorded by the *Challenger*, and from the Ceylon Pearl Banks.

Petrolisthes, sp.

A damaged specimen in the collection is referred to this genus. Carapace slightly longer than broad, a little compressed, surface marked with pubescent striæ, the hairs being short. Lateral margins entire, and slightly hairy. Superior orbital border straight, with a blunt external orbital projection. Rostrum prolonged deflexed, with a shallow median furrow, and the edges crenulate. Eyes large. Eye-peduncles short. Antennules minute. First joint of antennal peduncle reaching beyond margin of carapace. Chelipedes absent. Ambulatory legs short. Merus broad.

Length of carapace, 5 mm. ; breadth of carapace, 5 mm.

Colour in formalin : milky white.

Locality :—South-west of Beyt Island.

Galathea, Fabricius.

Galatea.—Leach (23), Desmarest (8), Latreille (22), De Haan (13), Stimpson (34), Haswell (14).

Galathea.—Fabricius (11), Milne-Edwards (9), Dana (7), Heller (16).

Rostrum flattened, and of moderate breadth, with the margins usually spinose. Carapace with pubescent transverse striæ, the surface usually unarmed, with the exception of the anterior gastric area. The cardiac area not prominent. Abdominal segments unarmed.

The members of this variable genus are usually confined to shallow water, where they live symbiotic on crinoids, or amongst coral, or on the surface and crevices of rocks. They swim backwards by curious movements of the tail.

The genus is more or less cosmopolitan.

Galathea elegans, White.—Plate, fig. 11.

Adams and White (1), Henderson (19), Miers (27).

Rostrum very long, and acute, two-thirds the length of the carapace and armed with seven small teeth on each side. Carapace and abdomen covered with a continuous series of pubescent striæ, and rather more than half as broad as long (including the rostrum). Lateral margins of the carapace armed with about eight teeth.

Antennæ minute. Antennal peduncle slightly elongated, the joints bearing acute spines on their anterior and posterior faces.

Chelipedes slender, one and two-thirds longer than the carapace and rostrum, and bearing a few spines. Fingers not gaping, and not half the length of the propodus. Colour yellowish, with three longitudinal dark purplish bands on the carapace, and one on either side of the chelipedes and legs.

One female bearing eggs.

Length of carapace and rostrum, 13 mm. ; breadth of carapace, 7 mm. ; length of chelipedes, 22 mm.

This species was found commensal on a species of black and white coloured Antedon.

Locality :—South-west of Beyt Island.

Previously recorded from :—Holborn Island, Haswell; Ceylon Pearl Banks, Southwell; Celebes Sea, Henderson; Borneo, Adams and White; Singapore, Walker; N. Australia, Haswell-Miers ; Amboina, de Man.

Munida, Leach.

Leach (23), Desmarest (8), Dana (7), Bell (4), Stimpson (34), Heller (16), Miers (26).

Rostrum slender and stiliform, with a well-developed supra-orbital spine on either side of the base. Carapace with the surface usually spinulose, and the cardiac area, as a rule, distinctly circumscribed.

Chelipedes and ambulatory limbs elongated and slender. One or more of the abdominal segments usually with a series of spinules on the antero-dorsal margin.

Very many members of this genus are deep-sea forms, extending down to 1,300 fathoms. A few are littoral, and occur in the crevices of rock or coral.

Munida spinulifera, Miers.—Plate, fig. 12.

Henderson (18), Miers (27).

Carapace a little elongated, and covered with a series of more or less continuous pubescent striæ. Edges of carapace armed with seven or eight spines. Rostrum a slender, conical, elongated, entire rod. Behind the rostrum, on each side, are four large spines, slightly less than the rostrum, and decreasing in size posteriorly. Eyes fairly large, and overhung by a few setæ. Peduncles rather short. Chelipedes long (twice as long as the carapace, including the rostrum), slender and hairy. The merus is elongated and bears three spines on its internal edge, and a few smaller ones on its outer edge. Carpus shorter than the merus, with one large spine on its anterior edge, and a row of about four smaller ones on its outer surface. Propodite as long as the fingers, with a number of smaller spines on both its inner and outer edge. Fingers gaping. Abdomen unarmed.

Several specimens, males and females. Natural colour: brick red.

Length of carapace and rostrum, 6 mm.; length of carapace, 3·5 mm.; length of chelipedes, 11 mm.

Localities:—(1) S.W. of Beyt Island; (2) S. of Adams Bridge, Ceylon.

Previously recorded from:—Amboina (Henderson); Arafura Sea (Miers).

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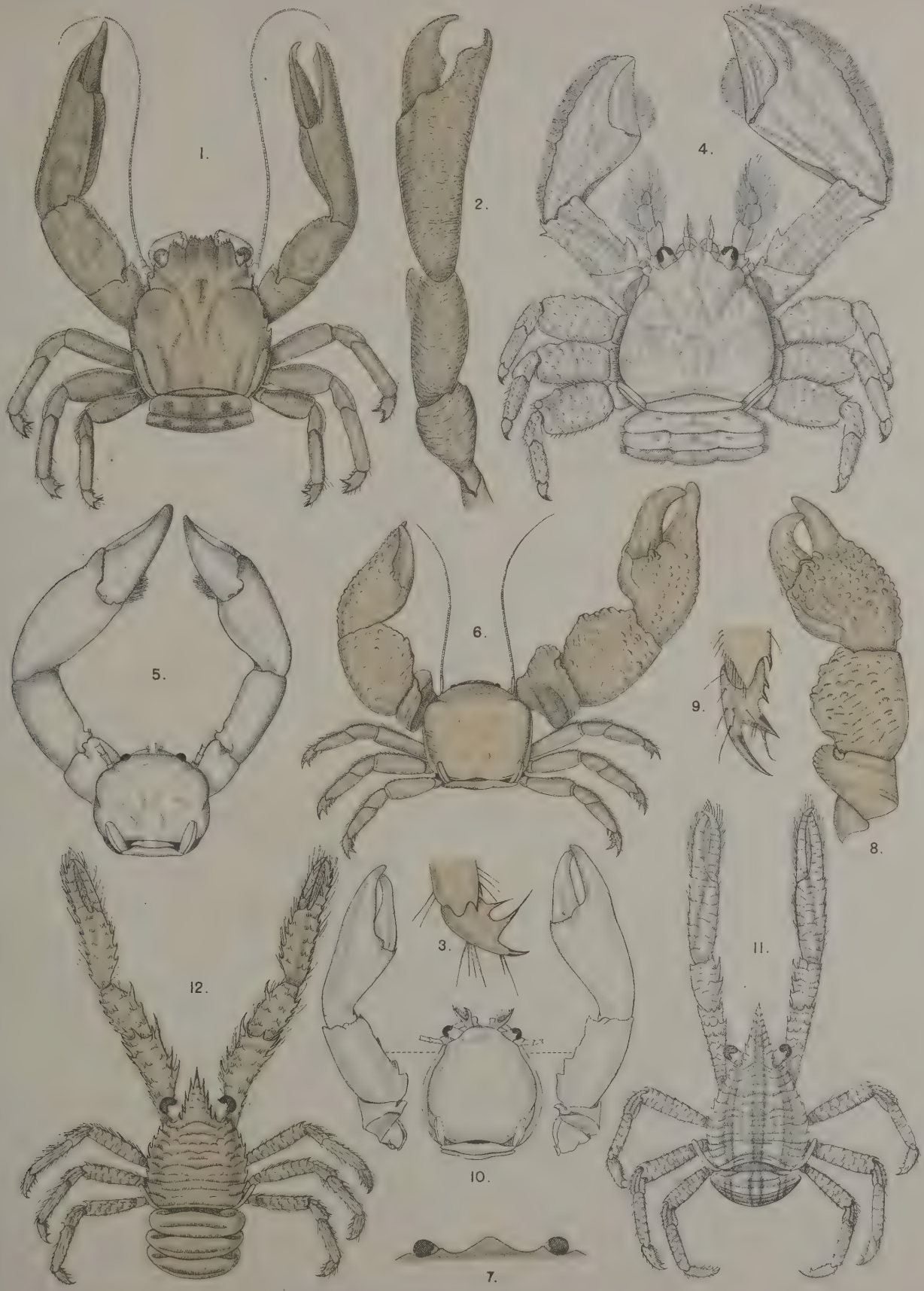
EXPLANATION OF PLATE.

ANOMURA.

Fig. 1. *Porcellana gaekwari*, n. sp. × 3.
„ 2. Right chelipede of same. × 5.
„ 3. Dactylopodite of second right walking leg of same. × 17.
„ 4. *Porcellana tuberculosa*, M. Edw. × $2\frac{1}{2}$.
„ 5. *Polyonyx obesulus* (White). × $2\frac{1}{4}$.
„ 6. *Polyonyx hendersoni*, n. sp. × 2.
„ 7. do. outline of rostrum.
„ 8. do. right chelipede. × $2\frac{1}{2}$.
„ 9. do. dactylopodite of second walking leg, greatly enlarged.
„ 10. *Petrolisthes armatus* (Gibbes), body without legs. × 2.
„ 10*a*. Chelipedes of same. × $2\frac{1}{3}$.
„ 11. *Galathea elegans*, White. × 2.
„ 12. *Munida spinulifera*, Miers. × $3\frac{1}{2}$.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REPORT

ON A

COLLECTION OF ALCYONARIANS

FROM

OKHAMANDAL IN KATTIAWAR

MADE BY MR. JAMES HORNELL IN 1904-5,

BY

PROF. J. ARTHUR THOMSON, M.A.,

AND

GEORGE CRANE, B.Sc., University of Aberdeen.

[With one Plate [1] and two Text-figures.]

In the course of an investigation of the shallow-water fauna of part of the Gulf of Kutch, Mr. James Hornell made a small collection of Alcyonarians which presents some features of interest. The precise district was the coast of Okhamandal, which forms the N.W. extremity of the Kattiawar Peninsula, and Mr. Hornell has called our attention to the fact that specimens of *Dendronephthya* or *Spongodes*, of *Lophogorgia*, *Astromuricea*, etc., could be collected at low tide.

The collection includes eight species, one of which—*Astromuricea stellifera*—is new. There is also a new variety of a remarkable species of *Echinomuricea* previously found in the Indian Ocean. The position of the various species may be indicated as follows :—

ORDER ALCYONACEA.

Family Alcyonidæ : 1. *Sclerophytum polydactylum* (Ehrenberg).

Family Nephthyidæ : 2. *Dendronephthya* (*Spongodes*) *dendrophyta* (Wright and Studer).

3. *Dendronephthya* (*Spongodes*) *brevirama* (Burckhardt).

[1] The artist's fee for drawing the specimens on this plate was paid by the Carnegie Trust for the Universities of Scotland, and I wish to thank the Trustees for helping me on this and other occasions to give worthy illustrations of the beautiful animals described.—J.A.T.

Order Axifera.

Family Muriceidæ: 4. *Astromuricea stellifera*, n. sp.
5. *Echinomuricea uliginosa*, Thomson and Simpson, var. *tenerior* n.

Family Gorgonidæ: 6. *Lophogorgia lutkeni*, Wright and Studer.
7. *Juncella juncea* (Pallas).

Order Stelechotokea. Section Pennatulacea.

Family Virgularidæ: 8. *Virgularia rumphii*, Kölliker.

ORDER ALCYONACEA. FAMILY ALCYONIDÆ.

1. **Sclerophytum polydactylum** (Ehrenberg).

Plate, fig. 5.

= *Lobularia polydactyla*, Ehrenberg.
= *Alcyonium polydactylum*, Dana.
For description see:—
Klunzinger: *Die Korallthiere des Rothen Meeres*, Part I. 1877, p. 26; Pl. I. figs. 6*a*–6*f*.
Pratt: *The Alcyonaria of the Maldives*, Part II. 1903, p. 524.

Several fine specimens are referable to this species, which is characterised by the absence of siphonozooids, the small size of the autozooids, and the tough, fleshy texture.

The largest specimen has the following dimensions: height, 5 cm.; length, 14 cm.; breadth, 8 cm. The lobes are much less digitiform than those figured by Klunzinger, being broader and flatter.

No autozooids occur on the stalk. They are most crowded towards the tips of the lobes. From ten to twelve may be counted on a linear centimetre.

The spicules closely resemble those figured by Klunzinger; the average size of the large warty spindles is 1·5 mm. by 0·3 mm., and of the small clubs 0·08 by 0·02 mm.

The colour of the colony is greyish-brown, and the surface, under the low power, has a peculiar reticulate appearance due to the presence of small superficial spicules.

Localities:—The specimens were obtained off Beyt Island, from Adatra Reef, and from Chindi Reef.

Previously recorded from:—The Red Sea, Maldives, Gulf of Mannar, Zanzibar, China Sea, British New Guinea.

FAMILY NEPHTHYIDÆ.

2. **Dendronephthya (Spongodes) dendrophyta** (Wright and Studer).

PLATE, fig. 4.

For description see :—

Wright and Studer : *Spongodes dendrophyta*. *Challenger Report*, Vol. XXXI. 1889, pp. 204, 205 ; Pl. XXXVI. c, fig. 2*a*, 2*b*.

Studer : *Alcyonarien aus der Sammlung des Naturhist. Museums in Lübeck*, 1894, p. 127.

See also Kükenthal, *Versuch einer Revision der Alcyonarien*. II. Die Familie der Nephthyiden. 2 Teil. *Zool. Jahrb.* xxi. (1905), p. 647, fig. 39.

Numerous umbellate specimens showing considerable diversity in size and appearance may be referred to this species. Several are of the open, loosely branching type, figured in the *Challenger* Report, but the majority have the polyps close-set and almost continuous on the surface of the polyparium as shown by Kükenthal. All are of an ovoid shape, markedly flattened from side to side. Typical dimensions are : height, exclusive of the stalk, 5 cm. ; diameter, 4 cm. and 2 cm. ; height of stalk, 4·5 cm. The largest specimen has a polyparium 7 cm. high, with diameters 6·5 cm. and 3 cm., and a stalk 2·5 cm. in height. The length of stalk varies considerably. There is a central axis from which spring several lateral branches ; these again subdivide two or three times and give rise to the polyp-bearing twigs. The twigs are grouped in fours or fives, and each bears about a dozen polyps. Even in the loosely-branched types the polyps are all borne on the surface of the polyparium, and immediately below those on the top of the stalk there are occasionally isolated twigs with a few polyps. Some of the lower branches are leaf-like.

The polyps are 0·55—0·6 mm. high and 0·6—0·7 mm. broad, with a stalk of about the same height as the polyp. The spicules on the polyps are arranged in eight double rows, each row containing usually four, but frequently five curved spicules (up to 0·24 mm. in length). The uppermost spicules of the rows do not project. The Stützbündel contains two rows of long warted spindles (2 mm. long), the uppermost projecting about half its length. On the superficial layers of the branches there are numerous long warty spindles (1·22 × 0·1 mm.), and the x-shaped spicules noted by Wright and Studer are also very numerous (0·17 mm. in diameter).

Reproductive bodies—probably sperm-sacs—occur in great abundance. The largest of these is 0·25 mm. in diameter. They are attached to the mesenteric bands far below the polyp stalks. The specimens were collected in the month of December.

Locality :—Rann Bay east of Poshetra, Okhamandal. Also off Kiu, Beyt Harbour.

Previously recorded from :—Chinese Sea and the Philippines.

3. **Dendronephthya (Spongodes) brevirama** (Burckhardt).

PLATE, fig. 6.

For description see :—

Burckhardt, E. : *Alcyonaceen von Thursday-Island (Torresstrasse) und von Amboina.* Semon's *Zool. Forschungsreisen*, vol. 5 (1898), p. 438, Pl. 31, fig. 5 ; Pl. 32, fig. 3*a*–3*e*.

Kükenthal, W. : *Versuch einer Revision der Alcyonarien.* II. Die Familie der Nephthyiden. 2 Teil. Die Gattungen Dendronephthya n.g. und Stereonephthya n.g. *Zool. Jahrb.* xxi. (1905), p. 659.

Several specimens of a distinctly umbellate type, with close-set polyparium somewhat flattened and presenting a continuous surface, are referable to Kükenthal's *florida* group of Umbellatæ, and agree in essential features with Burckhardt's *Spongodes brevirama.* Most of them vary in height from 3 cm. to 5 cm., exclusive of the short stalk portion, which is usually about 1 cm. in height, somewhat flattened, and with root-like attachments. In the smaller specimens the polyparium is almost hemispherical, in the larger forms it tends to be ovoid. It cannot be said that the polyparium is greatly flattened ; in one specimen the diameters were 4 cm. and 2·7 cm., in another they were 4·5 cm. and 3·5 cm. The collection also includes a very fine specimen ovoid in form and markedly flattened, with the following dimensions : height of the polyparium, 12·5 cm. ; diameters, 10·5 cm. and 5 cm. The stalk is practically suppressed, being reduced to about 1 cm. in height. The average length of the root-like attachments is 6 cm.

The lowest branches are very distinctly leaf-like in many of the specimens but not in all. Above these there are numerous approximately cylindrical main branches arising on all sides from a continuation of the stem. The main branches give off secondary branches, and these again give rise to the polyp-bearing twigs. The number of polyps borne by each distinct twig is very variable, but there are usually many bundles of about six each. The polyp-stalks are very short, and the polyps are confined to the surface of the polyparium. They are almost uniformly disposed on all sides. This is not in agreement with one of the features of the *florida* group, in which, according to Kükenthal, there is denser and more uniform distribution of polyps on the flatter surfaces. It does not seem to us necessary to attach much importance to such differences, which probably depend entirely on growth conditions. A feature of some interest on several specimens is the occurrence of a number of small twigs on the short stalk portion, almost down to the level of the stolons. Each twig bears two or three polyps.

The polyps are from 0·6 to 0·7 mm. in height by 0·5 mm. in breadth, and the stalks are about 0·8 mm. long. There are eight double rows of spindles on each polyp, each row containing five to seven spicules, the uppermost of which projects slightly. The spicules in each double row are arranged *en chevron*, and

the average size of the spicules is 0·14 by 0·03 mm. The single large Stützbündel spicule is strongly warted and is 1·8 mm. long by 0·08 mm. broad. It projects for about half its length. The superficial layers of the stem and stalk contain many large warty spindles (up to 2·6 × 0·2 mm.) and numerous smaller ones (0·8 × 0·06 mm.). The spicules of the canals are for the most part warty spindles (0·62 × 0·1 mm.) and a few smaller forms (0·17 × 0·05 mm.) which approximate to the stellate type.

Fig. 1.—*Dendronephthya brevirama*, showing close-set polyparium and anchoring stolons.

The colour of most of the specimens is a yellowish white, but individual polyps and even individual spicules of a deep rose-pink colour are found scattered here and there in the polyparium.

Localities:—S.E. of Beyt, 2–4 fathoms; Balapur Bay, low tide, and Mangunda Reef, Gulf of Kutch.

Previously recorded from:—China Sea and Torres Strait.

ORDER AXIFERA. FAMILY MURICEIDÆ.

4. **Astromuricea stellifera,** n. sp.

PLATE, figs. 1, 2, 3.

Some beautiful red fans, with the characters of the genus *Astromuricea*, seem to require the establishment of a new species. Of the three specimens examined the largest is 14 cm. in height, and 28 cm. in breadth. From a basal trunk (1·5 cm. high and 7 mm. thick) two main branches diverge, each giving rise to a flabellate system. The smaller of the two gives off a third fan parallel to the others, with which it anastomoses at several points. The colony is attached by a basal disc about 2 cm. in diameter. The main branches are 4 mm. in thickness, the larger is 25 cm. long and the smaller 15 cm.

A second specimen is 8 cm. high by 14 broad, with three main branches. The third specimen is somewhat incomplete, forming one-half of a fan 10 cm. high, with three main branches.

The branching is frequent, mostly alternate, and in one plane. The larger branches arise at an angle of about 60°, but this angle is often exceeded, and most of the smaller branches form an angle of 90°. Anastomosis is frequent among both large and small branches. The branches vary from 1 to 2 mm. in diameter, the smaller twigs being often slightly swollen at the tips. The colony is very flexible and not at all brittle.

The axis is horny, solid at the base, and hollow in the branches, of a dark glossy brown colour and almost smooth.

The verrucæ are closely crowded, and occur on all sides of the stem and branches, but in no regular order. In two of the specimens they project but little from the surface of the coenenchyma; in the third they project for about half their diameter. They are cylindrical in shape, with a diameter of from 0·5 to 1 mm. On their summit there is a circular aperture fringed by about a dozen projecting spiny spicules, similar to those with which the wall of the verruca is covered. The anthocodiæ are completely retractile within the mouth of the verruca. There is a low, almost horizontal operculum, formed by the convergent tentacles with their armour of spicules. On the aboral side of each tentacle lie two spicules converging towards the tip of the tentacle to form a very narrow isosceles triangle. Round the base of the tentacle there is a single or double ring of spicules.

The coenenchyma is moderately thick, and its surface presents under the lens a characteristically rough appearance.

The spicules of the coenenchyma are (1) numerous irregular warty stars and stellate toothed plates, 0·14—0·28 mm. in diameter; (2) a few stout spindles with close-set tuberculate warts of which the following measurements were taken: (length and

breadth in millimetres) 0·21 × 0·035, 0·23 × 0·04; 0·24 × 0·03, 0·28 × 0·05, 0·31 × 0·06, 0·45 × 0·12; (3) small forms—probably young—somewhat irregular in shape, but resembling the types just described, mostly about 0·12 mm. in length.

These spicules are of a fine pink or rose-red colour. A few are colourless. In the polyp the spicules seem to be confined to the operculum. They are long slender white spindles, somewhat bent, and bearing a few warts. They are from 0·14—0·18 mm. in length and 0·012—0·024 mm. in breadth.

The colour of the colony is between Venetian red and crimson and the polyps are white. Reproductive bodies were present in many of the polyps.

A stellifera may be distinguished from the other three species of *Astromuricea* by the character of the spicules fringing the mouth of the verruca. They do not exhibit any specially long needle-like processes as in the other species.

Locality:—Kiu, Beyt Harbour, low water, 24/12/05; also dredged off S.W. coast of Beyt Island.

5. **Echinomuricea uliginosa,** Thomson and Simpson (1909), var. *tenerior*, n. Plate, figs. 9, 10, 13.

The *Investigator* collection of littoral Indian Ocean Alcyonarians includes a new species of *Eckinomuricea* (*E. uliginosa*) which is described in detail by Thomson and Simpson in a memoir just about to be published. A variety of this species occurs in Mr. Hornell's collection.

The diagnosis of the species is as follows: A pinkish-red colony branched in one plane; the coenenchyma is thick and very rugose with spicules projecting in all directions; the verrucæ are thickly disposed, covering most of the surface; their walls bristle with the long smooth spines of projecting spicules; there is an elevated conical operculum composed of eight groups of three spindles and a collaret of two or three rows of transversely arranged curved spicules; each "point" consists of two bent spindles which touch for over three-quarters of their length but diverge near the collaret, the interspace being almost completely filled by a short, curved, transversely disposed spindle; the horny axis is brown, cylindrical, and chambered, firm and flexible below, soft and collapsible above; the spicules include a variety of forms, (*a*) some showing a projecting smooth spine with branching warty arms at the base, (*b*) spindles covered with irregular warts, (*c*) spindles bearing in addition to warts a number of smooth projecting spines on one side, (*d*) irregular forms with warty branches on one side and smooth spines on the other, (*e*) bifurcated spindles, (*f*) irregular plates with warty branches, and (*g*) smooth spindles in the anthocodiæ.

Locality:—Laccadives (Kalpeni Bank) and Arakan Coast, 13 fms.

The specimen from Kutch is a small unbranched colony, 65 mm. in height by 3 mm. in diameter. It is more delicate in appearance than the typical *Echinomuricea*

uliginosa and lighter in colour. This is especially noticeable in the case of the large pointed spicules surrounding the mouth of the verruca, these being deep red in the typical form, pink changing to white at the tip in the variety. The ground colour of the coenenchyma is white in the variety, red or pink in the type.

As to spicules, those of the variety are somewhat more delicate than those of the type, and bear longer spines. The chief difference between the variety and the type is that the superficial spicules of the coenenchyma in the variety are white spindles, with prominent rough warts, and reaching dimensions of 0·61 × 0·19 mm., while the corresponding spicules in the type are thick red spindles with short close-set warts, and of larger size, viz., 0·91 × 0·23 mm.

Locality :—Off Dwarka, 16 fms.

FAMILY GORGONIDÆ.

6. **Lophogorgia lutkeni,** Wright and Studer.

PLATE, fig. 11.

Challenger Report, xxxi. 1899, p. 150, Pl. XXX. fig. 1, 1*a*, XXXIV. fig. 1.

The collection includes several large and fine specimens of this species. The colonies are more copiously branched than the description in the *Challenger* Report

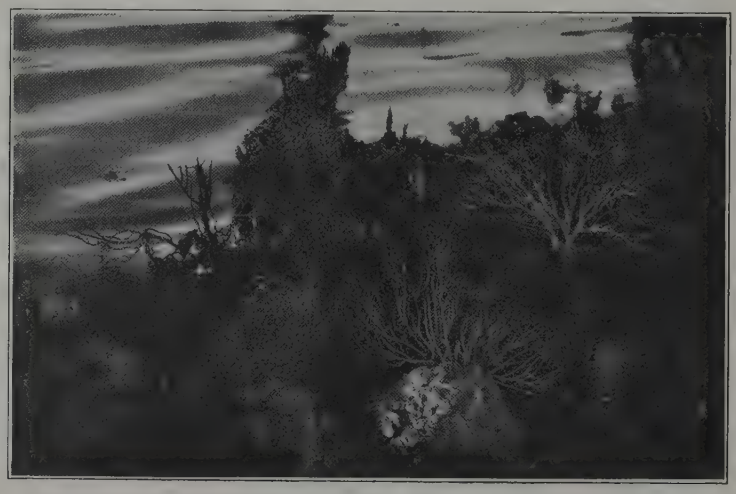


FIG. 2.—Gorgonids (*Lophogorgia lutkeni* and *Astromuricea stellifera*) exposed at low water, Kiu, near Beyt.

seems to indicate, and the largest Beyt specimen is about double the height of that obtained by the *Challenger*. The diameter of the main stem on the largest specimen is about 1 cm., and the height of the colony is 45 cm. There is much variety in

the conspicuousness of the verrucæ, for while in some places they stand out to the height of 1 mm., in others the openings are flush with the general surface. Under the low power the slit-like openings of the verrucæ show eight triangular lobes which cover the retracted tentacles. The verrucæ are uniform in size, with a long diameter of about 1·5 mm.

The spicules are on the whole smaller and more uniform than those in the *Challenger* specimen, the warty spindles being on the average 0·1 × 0·05 mm.

Locality:—The channel west of Beyt Island, 3–4 fathoms.

Previously recorded from:—Off Prince Edward Island, Ceylon, and Zanzibar.

7. **Juncella juncea** (Pallas).

Plate, fig. 14.

Gorgonia juncea, Pallas. Esper: *Die Pflanzenthiere*, 1797; *Fortsetzung*, p. 177, tab. lii.
Juncella juncea. Valenciennes, *Comptes Rendus*, xli. p. 14.
See Wright and Studer: *Challenger Report*, xxxi. 1889, p. 158, Pl. XXXIV. fig. 12.

Several specimens in this collection seem referable to this species. As Professor Hickson points out, there is great difficulty in distinguishing between *Juncella juncea* and *Juncella gemmacea*, since they agree in the prominence of the verrucæ, the thickness of the coenenchyma, the slight branching, and the nature of the spicules, which consist of clubs and double stars.

Ridley also calls attention to the slightness of the distinctions separating some of the species of *Juncella*, and the great variability in the characters.

Perhaps, as Professor Hickson suggests, *J. juncea* and *J. gemmacea* should be included in one rather variable species.

The present specimens are fragmentary, all except one unbranched. The verrucæ are very crowded, agreeing with Pallas's description. The largest specimen is 42 cm. long and varies from 7 mm. to 1·5 mm. in diameter. There is no definite arrangement of the verrucæ.

The colour of the branched specimen is yellowish-white, with a touch of red in some of the verrucæ. The other specimens have a buff colour.

The spicules consist of clubs and double stars with intermediate forms which show clearly the passage of the club into the double star. A few single stars were also found.

The following measurements were taken:—

Double stars—0·07 × 0·03; 0·09 × 0·035 mm.; 0·09 × 0·04; 0·1 × 0·04.

Clubs—0·08 × 0·025; 0·08 × 0·05; 0·09 × 0·03.

Single stars—0·04 mm. diameter.

Localities:—South end of Beyt Island, 3 to 4 fathoms; off Poshetra Point, 7 fathoms.

Previously recorded from:—Ceylon, Queensland, &c.

ORDER STELECHOTOKEA. SECTION PENNATULACEA.

8. **Virgularia rumphii**, Kölliker.

PLATE, figs. 7, 8, 12.

Kölliker: *Die Pennatuliden*, 1872, p. 202, figs. 123, 124.

Two specimens are referred to this species although showing certain departures from the type. The divergences seem to us to be merely quantitative. There is a long bare streak on the prorachidial surface, and a similar streak on the metarachidial surface, obscured, however, at the top by the interlocking pinnules. The pinnules are close-set. They have crowded polyps, a wavy outline, and the peculiar interlocking on the dorsal surface shown in Kölliker's figure. The axis is cylindrical below and flattened dorso-ventrally above. The calices of the polyps are indistinct, and thus very different from those of *V. multicalycina*, Thomson and Henderson.

The specimens differ from Kölliker's description in having a larger number of polyps on each pinnule (70 and 55 instead of 40—44). Siphonozooids cannot be clearly recognised, but this may be due to the imperfect preservation of the specimens. The superficial ramification of the canals on the prorachidial surface is only hinted at. The axis is more slender in our specimens than in Kölliker's description.

The following are the chief measurements:

	Specimen 1.	Specimen 2.	Kölliker's.
Total length	252 mm.	140 mm.	523 mm.
Length of rachis	211 ,,	104 ,,	422 ,,
Length of stalk	41 ,,	36 ,,	101 ,,
Breadth of pinnule-bearing part	5 ,,	4 ,,	6 ,,
Length of pinnules	11 ,,	4–6 ,,	—
Breadth of pinnules	1·5–2 ,,	1·5 ,,	3–3·5 ,,
Number of undeveloped pinnules	120 on each side	96 on each side	439 total
Number of developed pinnules	51	37	76+8 total
Number of polyps on each pinnule	70	55	40–44
Diameter of polyp	0·3 mm.	0·2 mm.	—
Diameter of axis below	0·7 ,,	0·8 ,,	3×2·7 mm.
Diameters of axis above	1×0·8 ,,	1·6×1 ,,	

Locality:—South-west of Beyt Island.

Previously recorded from:—Amboina.

EXPLANATION OF PLATE.

Fig. 1. *Astromuricea stellifera*, n. sp. × 10.
„ 2. *Astromuricea stellifera*, n. sp. Nat. size.
„ 3. *Astromuricea stellifera*, n. sp. Spicules.
„ 4. *Dendronephthya* (*Spongodes*) *dendrophyta* (Wright and Studer). Nat. size.
„ 5. *Sclerophytum polydactylum* (Ehrenberg). Nat. size.
„ 6. *Dendronephthya* (*Spongodes*) *brevirama* (Burckhardt). Nat. size.
„ 7. *Virgularia rumphii*, Kölliker. Nat. size.
„ 8. *Virgularia rumphii*, Kölliker. Dorsal or metarachidial surface showing the curious interlinking of the pinnules. × 5.
„ 9. *Echinomuricea uliginosa*, Thomson and Simpson, var. *tenerior* nov. × 1·5.
„ 10. *Echinomuricea uliginosa*, Thomson and Simpson, var. *tenerior* nov. × 10.
„ 11. *Lophogorgia lutkeni*, Wright and Studer. Nat. size.
„ 12. *Virgularia rumphii*, Kölliker. Ventral or prorachidial surface with a bare streak.
„ 13. *Echinomuricea uliginosa*, Thomson and Simpson, var. *tenerior* nov. Spicules.
„ 14. *Juncella juncea* (Pallas). × 1·5.

G. Davidson, del.

ALCYONARIANS.

REPORT

ON THE

NUDIBRANCHS

COLLECTED BY MR. JAMES HORNELL

AT

OKHAMANDAL IN KATTIAWAR IN 1905-6,

BY

SIR CHARLES ELIOT,
Vice-Chancellor of the Sheffield University,

WITH A NOTE ON THE PRESENCE OF SYMBIOTIC ALGÆ IN *MELIBE RANGII*, BY J. HORNELL.

[Text-Figures.]

The collection of Nudibranchs from the coast of Kattiawar sent me for examination by Mr. Hornell contains seven species, which I identify as follows :—

(1) *Chromodoris petechialis* (Gould).
(2) *Plocamopherus ceylonicus* (Kelaart).
(3) *Bornella digitata*, Adams and Reeve.
(4) *Melibe rangii*, Bergh. Probably = *M. fimbriata*, Alder and Hancock.
(5) *Antiopella indica*, sp. nov.
(6) *Pterælidia semperi*, Bergh.
(7) *Elysia grandifolia*, Kelaart.

With these are also some specimens of a small *Pleurobranchus* and of an *Oncidium*.

The collection, though small, has not been easy to identify. The specimens of known species present variations sufficient to throw doubts on the identifications

proposed, and the new species of *Antiopella* is so near to *A. novozealandica* that the question naturally arises if it is more than a variety. The obvious inference is that this corner of the Indian Ocean is developing varieties which are in a fair way to fix themselves as species. To the best of my belief the only other nudibranchs recorded from this coast are comprised in a collection made by Mr. W. Townsend partly at Karachi and partly at Maskat and on the coast of southern Persia. They were described by me in the *Journal of Conchology* for 1905, pp. 237–256. The species recorded from Karachi are **Bornella digitata*, *Thecacera maculata*, *Goniodoris modesta* (?), *Chromodoris semperi*, **Chr. petechialis*, *Doriopsilla miniata*, *Doridopsis rubra*. The two species marked with an asterisk are represented in the present collection.

Chromodoris petechialis (Gould).

Gould, *U.S. Exploring Exped.* 1838–42, vol. 12, p. 296; Atlas, figs. 391, 391 *a*; Eliot, Nudibranchs from the Pacific, in *Proc. Malac. Soc.* 1904, pp. 231–2; Eliot, Notes on a Collection of Nudibranchs dredged near Karachi and Maskat, in *Jour. of Conchol.*, 1905, pp. 250–1.

Two specimens of much the same size and appearance. They are about 26 mm. long, 22 mm. broad, and 12 mm. high, stout, broad and soft. At first sight the colour appears to be a uniform flesh tint without markings. On a closer examination, the mantle margins and portions of the dorsal surface are seen to be more opaque than the rest, and it is probable that in life there were spots on the back and a coloured border. The foot is grooved in front, but not notched, and there is a short, stout tentacle on either side of the mouth. The branchiæ are deeply retracted into the pocket, which is closed in both specimens : they are 12, simply pinnate, and yellowish.

The intestines are of a deep reddish purple, but the yellowish hermaphrodite gland (which is very small) forms a dendritic pattern contrasting strongly with the dark mass of the liver. The labial armature is purplish and forms a nearly complete ring, which, however, is interrupted at one point. The elements of it are minute bent rods which bear an accessory denticle near the tip and hence generally appear to have irregularly cleft ends. The formula of the radula is about $90 \times 85 . 0 . 85$. The first tooth is broad, with a shoulder projecting into the rhachis, and denticulate on both sides. The second tooth is also broad and denticulate on the outer side only. The remaining teeth are erect and bear 7–10 denticles on the outer side. Those at the end of the row are rather taller than is usual in the genus and bear 4–5 denticles on the apex.

I think these animals are the same as the specimens from Karachi described by me in the paper referred to above as *Chromodoris petechialis*. They are, however, twice as large and therefore have larger radulæ. It is impossible to say whether the spots and borders have faded or whether they were faint in the living animals. In the latter case, the specimens probably are the *Chromodoris picta* of Pease from the

Sandwich Islands (Pease in *Proc. Zool. Soc.* 1860, page 29), which will thus be a pale variety of *Chr. petechialis.*

Plocamopherus ceylonicus (Kelaart).

Alder and Hancock, *On a Collection of Indian Nudibranchiate Mollusca*, 1864, pp. 132–4. For *Pl. imperialis*, see Bergh in *Verhandl. der k.k. zoolog. botanischen Gesellschaft in Wien*, 1883, pp. 12–17, and for *Pl. ocellatus*, Eliot in *Linn. Soc. Journ. Zool.*, vol. 31, November, 1908.

Five specimens from Kiu. Their delicate and gelatinous consistency has caused all of them to be much contracted and distorted in the preserved condition, and it is difficult to give any satisfactory description of the external characters. The general shape was probably as in Alder and Hancock's figures of *Plocamopherus ceylonicus*: the oral veil very large, the branchial tuft large and central; the dorsal ridge on the tail only moderately developed, but distinct.

As preserved the specimens vary from 15 mm. to 35 mm. in length. The coloration also is variable and in many cases the epidermis has been rubbed off. As a rule the ground is transparent and colourless or faint yellow, but is covered in most parts by irregular mottlings of a beautiful brown of varying shade and intensity. They are deepest in colour and most regular in arrangement on the back. Among these mottlings are fairly numerous white or cream-coloured areas, distinct but irregular in outline. They are either plain or contain numerous small dots. The club-shaped tips of the dorsal processes are of a dull plum colour.

The large oral veil bears numerous processes (as many as thirty in large specimens), which are pinnate or sometimes bipinnate, but as preserved quite small, rarely attaining a millimetre in length. In all the specimens the head parts are much contracted and it is impossible to say anything about the tentacles or the pedal groove. There are three fairly large processes on either side of the back, much contracted, but evidently bearing several branches. They bear as a rule at the end a single round knob, which in all the specimens is of a dull plum colour and contrasts with the rest of the integuments. In three specimens all the processes have this knob: in one it is absent in the right anterior process, and in another both the anterior processes are ramified, but without a knob. This is the condition described by Alder and Hancock as found in *Pl. ceylonicus.* There are a few other smaller processes scattered over the back and sides. They are more numerous in one specimen than in the others. There are traces of processes on the caudal ridge. The branchiæ are large and strong, mottled like the back, and five in number. The rhinophores are whitish and retractile into cavities with papillate margins.

The labial plates are yellow or brown and triangular. The radula varies in colour from light yellow to dark brown. The rhachis is very broad and traversed by cross-lines. There are from fifteen to eighteen rows of teeth. The anterior rows

are incomplete and have a formula of about 7+3. 0. 3+7. In the hinder rows the number of teeth increases considerably and in the three specimens examined attained a maximum of 11+3. 0. 3+11, 12+3. 0. 3+12, and 15+3. 0. 3+15 respectively. The three innermost teeth are large and hamate, but the base of the first tooth does not project markedly into the rhachis as in some species. The fourth tooth bears a projection not amounting to a hook and there are traces of smaller prominences on the fifth and sixth. The outer teeth are flat plates.

The other internal organs are much as described by me for *Pl. ocellatus* (*l.c.*), but the œsophagus on issuing from the buccal mass begins to dilate almost immediately into a long stomach-like pouch, which varies in shape in the different specimens, and is constricted just before it enters the liver. The genitalia are small and appear to be immature or at least not functionally active. The dendritic prostate characteristic of the genus is present, but smaller than in the specimens of *Pl. ocellatus* which I have examined.

I think these specimens are probably a variety of *Pl. ceylonicus*. They agree with Alder and Hancock's description in most points, but still present differences of some importance. (1) The skin is much smoother and not covered with so many papillæ and processes. But such projections often disappear when a soft animal shrinks and contracts in the preserving fluid. (2) The radula is rather broader; but it is probably variable, and Alder and Hancock do not indicate that they examined more than one specimen. (3) The plum-coloured knobs are not mentioned in their description and must be a peculiarity of this variety. Except for the colour, the dorsal processes in one specimen correspond exactly with Alder and Hancock's account.

Since *Pl. imperialis*, Angas, has purple knobs on the dorsal processes (but only on one pair) it would be natural to refer these specimens to it, but they seem to differ from it in some points more decisively than from *Pl. ceylonicus*. (1) *Pl. imperialis* is said to have two dorsal ridges which meet in a point behind. The present specimens show no trace of such a ridge. (2) *Pl. imperialis* has 5–7 hamate teeth, but in the present specimens the number of hamate teeth is consistently three only. But I should not be surprised to find that *Pl. ceylonicus* and *Pl. imperialis* pass into one another by gradual modifications.

Pl. ocellatus from the Red Sea offers few points of structural difference from *Pl. ceylonicus*, but superficially the present specimens do not resemble those sent me by Mr. Crossland.

Bornella digitata, Adams and Reeve.

Eliot, *Proc. Zool. Soc.* 1904, vol. 2, pp. 100–2, and references there quoted; and *id.* in *Journ. of Conchol.* 1905, p. 238.

One specimen from Chindi reef. As preserved, it is colourless, somewhat bent, but about 35 mm. long if straightened out, and stoutly built. The rhinophore sheaths bear three short processes in front and a long one behind. Besides the rhinophore

sheaths there are six pairs of cerata : the first pair are trifid ; the second, third, and fourth are bifid ; the fifth and sixth are simple.

The specimen is of the same type as those from Karachi described by me in the *Journal of Conchology* (*l.c.*). The species is probably common in these waters.

Melibe rangii, Bergh. Probably = *M. fimbriata*, A. and H.

See Bergh, *Malacol. Untersuch.* ix. 1888, pp. 370–6, and Alder and Hancock, *Notes on a Collection of Indian Nudibranchiate Mollusca*, 1864, pp. 137–9.

Seven specimens from Kiu, Okha. The largest is about 80 mm. long, but as it is bent this represents a real length of at least 100 mm. The general colour is a very faint transparent hyaline green, which allows the pink and white viscera to be seen clearly. The muscles are also clearly visible as a network of intersecting stripes. In places there are brownish spots and all the processes, filaments, cirrhi of the hood, &c., tend to be olive green, especially on the upper parts of the animal.

The back bears from six to eight pairs of large cerata.[1] In the best preserved specimen, which is only 55 mm. long, they are 21 mm. high. In some cases, however, they are quite small, even near the middle of the back. This is apparently due to the full-grown cerata having fallen off and been replaced by fresh growths. Most of the cerata in the present collection are detached and show a configuration like that depicted by Bergh for *Melibe vexillifera* (Bergh, *Verh. d. k.k. zool. bot. Ges. in Wien*, 1880–1, Pl. II. fig. 3), namely, a globular tuberculate base bearing a thinner crest with jagged membranous edges. But in the specimen where the cerata remain *in situ* they are tall and wedge-like, and this is probably the natural shape, the other being due to distortion caused by the contraction of the base. Besides cerata there are on the surface of the body : (1) small low tubercles, simple or compound, especially numerous on the sides and on the hood ; (2) largish pointed papillæ ; (3) simply ramified processes, as much as 12 mm. high, especially numerous on the back. The rhinophore sheaths are tall, slender, and provided with one or more long digitate processes. The club of the rhinophores is small ; opaque white or yellowish. The opening of the hood is circular and bears inside three or four irregular rows of long (as much as 14 mm.) snaky cirrhi. The lips are not raised and the mouth is merely a roundish opening surrounded by very small papillæ.

The mouth opens into a tube more or less coloured with dark pigment. In its walls are embedded two small jaws, yellowish, membranous, and irregularly denticulate. A short laminated œsophagus leads directly into the stomach, which is surrounded by a very distinct girdle of about forty plates. They vary considerably in colour (red, yellow, or grey) and in size, but do not alternate regularly. Behind

[1] For details respecting the appearance of these cerata when fresh, see Mr. Hornell's note and figures, pp. 145–7 below.

the girdle comes a constriction, and the posterior part of the stomach is soft and laminated. From it issues the large intestine, which is laminated internally and provided with a ridge. It runs straight to the anus, which is situated just in front of the second of the cerata on the right side. At the point where the intestine issues from the stomach is a diverticulum with puckered walls. The liver is a mass of small tubes, white or yellowish, which completely surround the hermaphrodite gland. It consists of three portions: a very small one on the right of the stomach and a rather larger one on the left uniting with the posterior portion, which is much the largest of the three. The livers send up prolongations which enter the dorsal integuments and reach the base of the cerata, but I could not discover either by external examination or by sections any trace of hepatic diverticula within the cerata.

The hermaphrodite gland, which is entirely surrounded by the liver tubules, consists of a great number of globules. Its duct is long and leads into a long ampulla bent upon itself several times. After the bifurcation, the female branch becomes broad, flat and puckered, forming a complete loop (the "Schlinge" in Bergh's description of *Melibe rangii*). It then contracts again. The spermatotheca is elongated and has a short broad duct. The male branch passes almost immediately into the large spherical prostate, which consists of two portions, the smaller yellow or greenish and the larger pink. From this pink portion issues the thin but muscular *vas deferens*, which forms two coils and then passes into the penis. This organ is long, dagger-shaped, and either straight or bent. In most of the specimens examined the genitalia were small, but in one the mucus and albumen glands were swollen to an enormous size, and distended the interior part of the body. The pink prostate is a conspicuous object even externally, as it can be seen through the integuments. In the central nervous system the ganglia are strongly granulated and not distinctly divided from one another.

These specimens seem referable to *Melibe rangii*, Bergh, but this species (1888) is probably the same as the earlier *M. fimbriata* of Alder and Hancock, 1864. There are some external differences, and A. and H. state that their species has no jaws, but I have shown (in *Jour. of Conchol.*, vol. 12, No. 3, July, 1907, pp. 90–1) that this statement is probably an error. But as there can be little doubt that these specimens are *M. rangii*, I use that name until the identity with *M. fimbriata* can be established.

The only feature which militates against the identification of these specimens with *M. rangii* is that they have no trace of hepatic diverticula within the cerata, although the liver extends to the base of the cerata. It is probable that different individuals show diversity in this respect, as in *Dendronotus* and *Bornella*.

From an examination of the living animals, Mr. Hornell was led to think that symbiotic algæ might be present in the small ramified processes borne by the cerata,

and in other brownish portions of the integuments. The integuments, as preserved, do not in any way discountenance this supposition, but in their present condition they do not afford good material for histological examination. Mr. Hornell's notes and drawings are therefore appended without addition.

In the *Quarterly Journal of Microscopical Science* (March, 1908, pp. 287–8), Mr. Evans and myself indicated the possible presence of symbiotic algæ in the dorsal regions of *Doridoeides Gardineri*.

Antiopella indica, sp. nov.

For the synonymy Antiopella = Janus = Antiopa, see Eliot, Notes on some British Nudibranchs, *Journ. Mar. Biol. Assoc.*, 1906, p. 373.

Two specimens marked Kiu, Okha. They are solidly built with flat backs. The measurements of the larger are: length 11 mm.; breadth across the rhinophores, which is the widest part, 6·5 mm.; height 5·5 mm.

The integuments are transparent, but the general coloration is somewhat mottled because the pinkish, whitish, and greenish intestines show through the back, foot, and sides. Also on the back, lips, rhinophores and crest, anal papilla and sides are scattered quite irregularly small reddish-brown spots. The cerata are greenish-grey and the parts of the back near them seem to be marked with faint light stripes running towards the margin.

The cerata are arranged along the margin of the back, at most two or three deep. They are small (largest 1·5 mm. high), thin, and not like those of most Janidæ. They extend in front of the rhinophores. These latter, as well as the crest between them, are well developed and thickly perfoliate. The anal papilla is very large: it is set far back in the medio-dorsal line. The genital orifices are about 3·5 mm. from the head and not conspicuous. The oral tentacles are indistinct. The foot is moderately broad.

The buccal mass is large. The jaws are red and bear a single series of very large denticles. The tissues around them are pinkish-white. The formula of the radula is 21 × 31. 1. 31 as a maximum, but the front rows are only 12. 1. 12, the number of teeth increasing rapidly in the hinder rows. The teeth are thin, transparent, and colourless, of the hamate type usual in the genus and not denticulate. They are somewhat crowded, but the rhachis is wide and the median teeth plain. The stomach and the liver tubes which communicate with it are very thin and not at all muscular. A hepatic duct enters the stomach on either side and a third behind. These ducts give off branches which enter the integuments and form a spongy layer under the cerata.

The anterior genital mass is pinkish and of small size. The spermatotheca, however, is large, elongated, and in the specimen examined empty. The hermaphro-

dite gland is in two divisions which are united below the posterior parts of the alimentary organs, but rise up above them on either side. It consists of large, clear, pinkish packets of follicles. The central nervous system is much as in Bergh's figures of *Janolus australis* (*Challenger* Report, 1884, Pl. IX. fig. vi.). The eyes are stalked.

In many ways this animal resembles *A. novozealandica* and the two may even be varieties of one species. But as preserved they are not very similar in appearance; the colour is not the same and the cerata and rhinophores are smaller in this species.

Pteræolidia semperi, Bergh.

See Bergh, *Beitr. zur Kennt. der Aeolidiaden*, iii. p. 22, and *Malac. Untersuch.* i. p. 18 (1870), under Flabellina; Eliot, *Proc. Zool. Soc.* 1903, pp. 255–6.

Five specimens from Kiu, Okhamandal. They are coiled up, but are about 40–50 mm. long. The colour as preserved has become a transparent yellowish-white, but traces of red and green can be seen. The shape is slender and elegant. There are from fifteen to twenty groups of cerata which are not at all caducous. The anterior angles of the foot are produced and deeply grooved. The oral tentacles are large; the rhinophores small, stout, and lamellated. The dorsal margin is not marked by a ridge.

In the specimen dissected the radula consists of a single row of eighteen teeth, bearing eight denticles on either side of the central cusp. The cutting edge of the jaws is armed with many rows of denticles.

Pteræolidia semperi is recorded from the Philippines, Zanzibar, and Japan, and is probably generally distributed in the Indo-Pacific. It is a beautiful creature when alive, with a complicated coloration which produces a general effect of purple with a greenish silvery glaze.

Elysia grandifolia, Kelaart.

Kelaart, *Ann. and Mag. Nat. Hist.* 1859, vol. iii. p. 493; Eliot, *Proc. Zool. Soc.* June, 1906, p. 689.

Seven specimens from Kiu. The largest are about 30 mm. long and 20 mm. broad. The colour is somewhat variable, but the best preserved specimens indicate that it was olive green, with a very distinct border to the wings and rhinophores which is now white but shows signs of having been yellow. This border is accompanied on the outside by a second thinner line of black, very distinct where it occurs, but often interrupted and in one specimen entirely absent. The head is large, the tail long and pointed. The pericardial prominence is of varying shape, but generally elongate. The radula of the specimen examined had eight teeth in the ascending series, twelve in the descending, and about thirty in the heap of various sizes. The lower edge of the teeth

is very minutely serrulate. The ramifications of the liver extend to the extreme edges of the wings and tip of the tail and are very distinctly visible from the outside.

As pointed out in my paper referred to above, there is much confusion in the nomenclature of the tropical *Elysiidæ*, but Kelaart's names appear to be the earliest and *grandifolia* should be kept as the specific designation of a large species with a pointed tail and typically of a green colour with two borders, yellow and black, which, however, are not developed in all specimens.

A NOTE ON THE PRESENCE OF SYMBIOTIC ALGÆ IN THE INTEGUMENTS OF NUDIBRANCHS OF THE GENUS *MELIBE*,

By JAMES HORNELL.

During the Ceylon pearl fishery of 1905, when making my daily visit of inspection to the boats at work, it was my habit occasionally to board one or more to note the progress and conduct of the diving operations. One day in February when aboard a boat fishing on the South Moderagam Par in six fathoms, my eyes fell upon a handful of flaccid brown masses in a diver's net just drawn up. My first thought was that they pertained to some species of *Aplysia*, several of which are extremely abundant at times on the pearl banks: I was about to pass them as of no importance when a something unfamiliar in their appearance caused me to reach forward to take possession. But a diver a second before I could pick them up flung the greater part back into the sea and I had but four left.

These I examined on return to my quarters, and then found them of greater interest than I had imagined. The four masses were practically identical in form, colouring, and size; none showed any trace of alimentary canal or of any orifice whatever, but each showed a disc-shaped place of attachment, 5 mm. in diameter, on one surface. Each mass was laterally compressed, stout and fairly thick towards the disc of attachment, thence narrowing gradually to a thin crest-like ridge upon the upper margin, and in general form closely resembling the crested pneumatophor of *Physalia*. In vertical transverse section it was distinctly pyriform in outline. The ground coloration was of two shades of brown, irregularly distributed, and flecked here and there with small irregular patches of grey.

When I handled the masses first, the surfaces were covered with closely-set, low wart-like papillæ irregularly distributed, at some places more or less aggregated in fairly densely-set groups, at others rather widely separated from one another. After immersion in water for some minutes, the appearance underwent a considerable

change ; each mass plumped out and each of the wart-like papillæ became the base of a tiny arborescent tuft of branching threads. The general substance possessed a certain amount of contractility when irritated, shrinking away when touched, while the arborescent tufts suffered complete retraction at the place affected. The tufts did not again expand fully for quite a minute after the cause of irritation ceased.

Examination under the microscope resolved each arborescent tuft into a group of digitate papillæ having perfectly colourless transparent walls, so tenuous as not to be visible to the unaided eye. In each digitation was a branched or dendritic tuft made up of brown cell-rows having a very close resemblance to the branching threads of certain filamentous algæ. It was the massing of these branched threads that gave the arborescent appearance to each of the tufts referred to above (Figs. 1 and 2).

The cells of these branched strands were of uniform diameter, and each had a well-defined nucleus. Besides forming the threads within the digitate papillæ these cells were also found in masses spread over the general surface of the organism and forming brown patches here and there according to the relative abundance of the cells. Other patches of brown, but deeper in tint and with a shade of red in it, formed the remainder of the brown coloration of the surface, and wherever such reddish-brown patches were, a great abundance of very minute red-brown cells was indicated, the cells aggregated into rows (Fig. 8) or into irregular masses (Fig. 9). Few or none of these minute brown bodies were met with in the digitate papillæ.

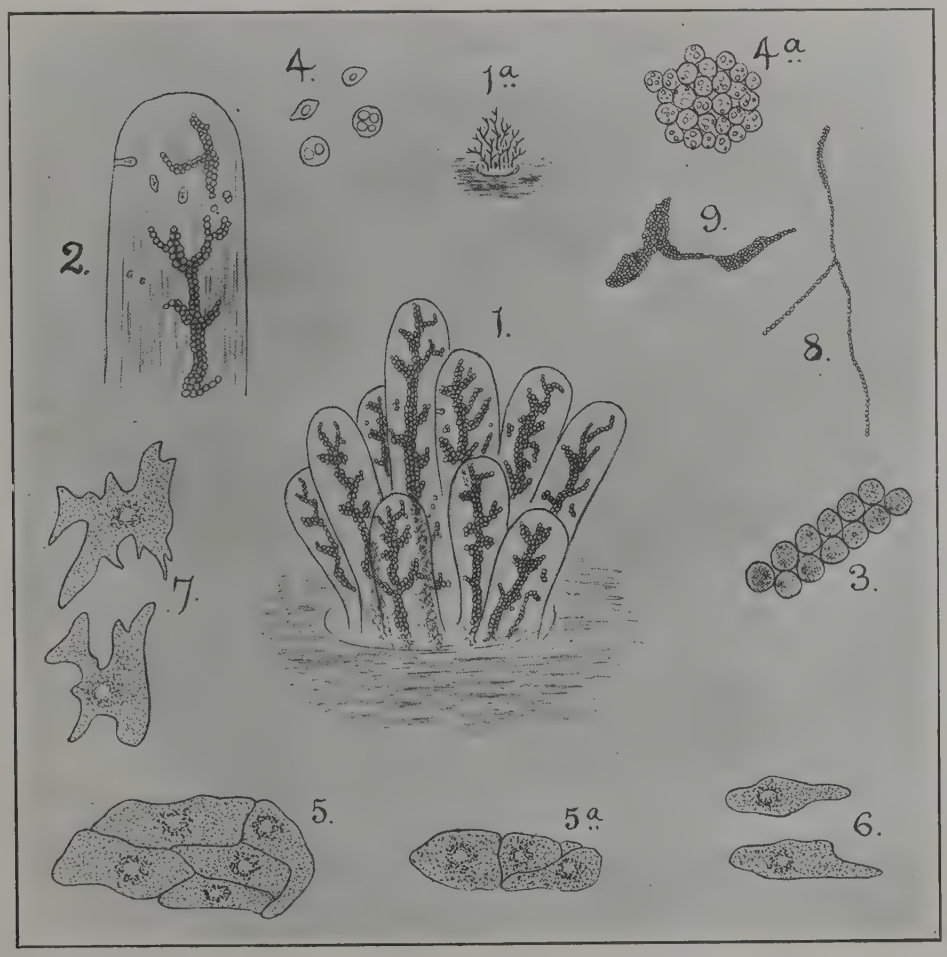
The surface patches coloured grey were seen under the microscope to be composed of granular cell-tissue, apparently colourless (Figs. 5 and 6). In each cell was a clear spherical nucleus. The cells were irregular in outline, varying considerably, but agreed usually in being elongated along one axis, so that they often formed strand-like tracts. This grey tissue had a superficial resemblance to squamous or tabular epithelium. It appeared to be restricted to the surface, but here and there at some distance from the surface were small centres of a pale yellowish tissue made up of cells, which, if not identical, appeared to be closely related ; indeed, the only perceptible difference was that these more deeply seated cells were irregularly stellate in outline (Fig. 7).

The mass of the organism was distinctly areolar, large rounded cavities occupying the greater part of the interior, separated more or less by a network of fine colourless strands which appeared to be muscular. These colourless fibres were specially distinct within the digitate papillæ. On some of the threads protoplasmic centres could be seen, each with a nucleus. A few gland-like bodies were observed in the digitate papillæ, containing secretion matter in the lumen. One was noticed to open by a well-marked orifice upon the surface. Associated with the brown cellular strands,

apparently algal, were quantities of clear, rounded, colourless cells filled with refractive granules (Figs. 4 and 4*a*).

The above notes were made during a rough examination of the living tissue. As I was greatly pressed for time, they are necessarily superficial; time and opportunity to carry the inquiry further have both been lacking.

For some time I was unable to satisfy myself as to the nature of the organism. As the handful of its separate masses was all in one diver's bag, I inferred that they had been grouped together when torn from their attachment by the diver, their sessile manner of growth being shown by the small discous scar which each bore. The apparently symbiotic conjunction of animal and plant (algal) tissues puzzled me, as did the lack of any indication of alimentary or other canal. Later, I was able to identify the masses as cerata from the dorsum of a large Nudibranch of the genus *Melibe*, the *M. rangii* of Bergh.



EXPLANATION OF TEXT FIGURES ON PRECEDING PAGE.

Fig. 1. Group of digitate papillæ, as seen under a hand lens.

The walls of the papillæ are extremely delicate and perfectly transparent, and are not visible to the naked eye, which sees only the branching strands of brown algæ. To the unaided vision a group of these papillæ appears as a much branched, brown arborescent tuft (Fig. 1*a*).

Fig. 2. Distal portion of a papilla more highly magnified, showing gland-like bodies and a branching algal strand.

The fine lines would appear to represent muscular fibres penetrating the papilla.

Fig. 3. A double row of algal cells from a papilla yellowish-brown in life.

Fig. 4. Colourless cells with clear refractive granules within.

Fig. 4*a*. A group of the same found associated with the algal threads.

Figs. 5 and 5*a*. Groups of cells from grey patches on the surface of the main mass of the organism. Under the microscope this grey matter is seen to consist of irregularly shaped cells, not unlike squamous epithelium—contents granular and apparently colourless. A clear nucleus in each.

Fig. 6. Two isolated cells of same, showing characteristic elongated form.

Fig. 7. Two irregularly stellate cells from slightly yellowish tissue from a little way below the surface; the granular contents and clear nuclear centres are similar in appearance to those of cells from the grey surface tissue

Fig. 8. Strings of very minute cells, dark brown in colour, with a tinge of red. Found mostly in the surface layer of the mass.

Fig. 9. Irregular mass of the same cells as depicted in Fig. 8.

Figs. 2—9 drawn under $\frac{1}{8}$ in. Beck obj.

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